
फिर से भरे जा सकने वाले परिवहनीय
निर्बाध एल्युमीनियम मिश्र धातु गैस
सिलेंडरस — विशिष्टि
(पहला पुनरीक्षण)

**Refillable Transportable Seamless
Aluminium Alloy Gas Cylinders —
Specification**
(*First Revision*)

ICS 23.020.30

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली-110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.gov.in www.standardsbis.in

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Gas Cylinders Sectional Committee had been approved by the Mechanical Engineering Divisional Council.

This standard is intended for refillable transportable seamless aluminium alloy gas cylinders for transportation and storage of compressed, permanent and liquefiable gases.

The purpose of this standard is to provide a specification for the design, manufacture, inspection and testing of the cylinders in common use and approval of refillable transportable seamless aluminium alloy gas cylinders.

In this revision, efforts have been made to align with ISO 7866 : 2012 'Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing'. This standard was originally issued in 2006. In this revision all the amendments have been incorporated.

While implementing this standard, the manufacturer and the inspection agency shall ensure compliance with statutory regulations.

Owners and users of cylinders should note that cylinders designed to this standard are to operate safely, if used in accordance with specified service conditions. It is the responsibility of the owners and the users to ensure that the cylinders are periodically tested as per norms laid down in *Gas Cylinder Rules, 2004* as amended from time-to-time and as enforced by statutory authorities under the rules.

The requirements for periodic inspection and testing of seamless aluminium gas cylinders are covered in IS 16017 : 2013 'Transportable gas cylinders — Periodic inspection and testing of seamless aluminum alloy gas cylinders'.

The relevant SI units and corresponding conversion factors are given below for guidance:

$$\begin{aligned}\text{Pressure 1 Pa (Pascal)} &= 1 \text{ N/m}^2 \\ 1 \text{ kgf/mm}^2 &= 9.806 65 \text{ MPa}\end{aligned}$$

The composition of the Committee responsible for the formulation of this standard is given in Annex H.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard*REFILLABLE TRANSPORTABLE SEAMLESS ALUMINIUM
ALLOY GAS CYLINDERS — SPECIFICATION*(First Revision)***1 SCOPE**

This standard lays down the minimum requirements for the material, design, construction and workmanship, manufacturing processes and tests of refillable seamless aluminium alloy gas cylinders of water capacities from 0.5 litre up to and including 150 litre for compressed, liquefied gases except liquefied petroleum gases (LPG).

NOTE — If so desired, cylinders of water capacity less than 0.5 litre may be manufactured and certified to this standard.

2 REFERENCES

The standards listed below contain provisions, which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standard indicated below.

<i>IS/ISO No.</i>	<i>Title</i>	<i>IS/ISO No.</i>	<i>Title</i>
1500 : 2005	Method for Brinell hardness test for metallic materials (<i>third revision</i>)	5844 : 2014	Hydrostatic stretch testing of compressed gas cylinders — Recommendations (<i>first revision</i>)
1586 : 2000	Method for Rockwell hardness test for metallic materials (Scales A-B-C-D-E-F-G-H-K, 15N, 30N, 45N, 15T, 30T and 45T) (<i>third revision</i>)	6051 : 1970	Code for designation of aluminum and its alloys
1599 : 2012	Metallic materials — Bend test (<i>third revision</i>)	7202 : 1974	Inspection gauges for checking type IV (size 1, 2, 3) taper threads of gas cylinder valves and cylinder necks — Specification
1608 : 2005	Metallic materials — Tensile testing at ambient temperature (<i>third revision</i>)	7241 : 1981	Glossary of terms used in gas cylinder technology (<i>first revision</i>)
3224 : 2002	Valve fittings for compressed gas cylinders excluding liquefied petroleum gas (LPG) cylinders — Specification (<i>third revision</i>)	9122 : 2008	Inspection gauges for checking type 2 taper threads of gas cylinder valves, taper 3 in 25 — Specification (<i>first revision</i>)
3933 : 1966	Colour identification of gas cylinders and related equipment intended for medical use	15683 : 2006	Portable fire extinguisher — Performance and construction — Specification
4379 : 1981	Identification of the contents of industrial gas cylinders (<i>first revision</i>)	15894 : 2011	Inspection gauges for checking type 1 (sizes 1, 2 and 3) taper threads of gas cylinder valves and cylinder necks — Taper 1 in 16 on diameter — Specification
		16017 : 2013	Transportable gas cylinders — Periodic inspection and testing of seamless aluminium alloy gas cylinders
		IS/ISO 11114-1 : 2012	Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents
		ISO 209 : 2007	Aluminium and aluminium alloys — Chemical composition
		ISO 7539-6 : 2011	Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of pre-cracked specimens
		ISO 9809-2 : 2011	Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 2: Quenched and tempered steel cylinders with tensile strength greater than or equal to 1 100 MPa

3 TERMINOLOGY

For the purpose of this standard, the following definitions and those given in IS 7241 except for the following shall apply.

3.1 Yield Stress (R_e) — Value corresponding to the lower yield stress R_e or for steels that do not exhibit a defined yield, the 0.2 percent proof stress (non-proportional elongation) $R_{p0.2}$.

3.2 Solution Heat Treatment — Thermal treatment which consists of heating the products to a suitable temperature and holding at that temperature long enough to allow constituents to enter into solid solution.

3.3 Quenching — Controlled rapid cooling in a suitable medium to retain the solute phase in solid solution.

3.4 Artificial Ageing — Heat treatment process in which the solute phase is precipitated to give an increased yield stress and tensile strength.

3.5 Batch — Quantity of up to 200 gas cylinders, plus cylinders for destructive testing, of the same nominal diameter, wall thickness, length and design, made successively from the same cast of aluminium alloy and subjected to the same heat treatment on the same equipment for the same duration of time.

3.6 Design Stress Factor (F) (Variable) — Ratio of equivalent wall stress at test pressure (P_h) to the guaranteed minimum yield stress (R_e).

3.7 IAA — Registration record of international alloy designations and chemical composition limits for wrought aluminium and wrought aluminium alloys as published by the Aluminium Association.

3.8 Mass — Mass of a cylinder, expressed in kg, comprising the combined mass of cylinder and permanently attached parts (for example, foot ring, neck ring, etc) but without valve.

3.9 Working Pressure (P_w) — Working pressure for gas means the settled internal pressure of the gas in the cylinders at a temperature of 15°C.

3.10 Test Pressure (P_t) — Test pressure (P_h) means the internal pressure required for the hydrostatic test or the hydrostatic stretch test of the cylinders.

3.11 Burst Pressure (P_b) — Highest pressure reached in a cylinder during burst test.

4 SYMBOLS

- a — calculated minimum thickness, in millimetres, of the cylindrical shell (*see* Fig. 1)
- $\acute{a}$ — guaranteed minimum thickness of the cylindrical shell, in mm,

- A — percentage elongation determined by the tensile test.
- b — guaranteed minimum thickness, in millimetres, at the Centre of a convex base (*see* Fig.1)
- D — nominal outside diameter, in millimetres, of the cylinder (*see* Fig.1)
- D_1 — nominal outside diameter of the cylinder neck, in mm (*see* Fig.3).
- D_f — diameter of former, in mm (*see* Fig.6)
- E — modulus of elasticity in MPa
- F — design stress factor (variable) (*see* 3.6)
- H — outside height, in millimetres, of domed part (convex head or base end) (*see* Fig.1)
- L_o — original gauge length, in mm (*see* Fig.5)
- N — ratio of the diameter of the bend test former to the actual thickness of the test piece (t)
- P_b — actual burst pressure, in bar, above atmospheric pressure
- P_h — hydraulic test pressure, in bar, above atmospheric pressure
- P_y — observed pressure when gas cylinder starts yielding during hydraulic bursting test, in bars above atmospheric pressure
- P_w — working pressure above atmospheric pressure, in bar
- R — inside knuckle radius, in mm (*see* Fig.1)
- r_i — inside crown radius, in mm (*see* Fig.1)
- R_e — minimum guaranteed value of yield stress, in MPa (*see* 3.1)
- R_{ea} — actual value of the yield stress, in MPa, as determined by the tensile test specified in 9.2
- R_g — minimum guaranteed value of tensile strength, in MPa
- R_m — actual value of the tensile strength, in MPa, as determined by the tensile test specified in 9.2
- S_o — original cross-sectional area of tensile test piece, in mm²
- T — actual thickness of the test specimen, in millimetre
- t_m — average cylinder wall thickness, in millimetres, at the position of test (*see* Table 2)
- U — ratio of the distance between knife edges to the average cylinder wall thickness t_m at the position of test
- W — width, in millimetres, of the tensile test piece (*see* Fig. 5)
- T — titre of hydrogen peroxide in g per litre
- Z — correction factor

5 MATERIALS

5.1 General Requirements

5.1.1 Aluminium alloys and their chemical composition limits shall be as specified in Table 1. Other aluminium alloys may be used to produce gas cylinders provided they satisfy all the requirements of this standard and are approved by the statutory authority.

5.1.2 The gas cylinder manufacturer shall identify the gas cylinders with the particular casts of the alloy from which they are made, and shall obtain and provide certificates of the analysis of the casts used. If check analysis is required, they shall be carried out either on test specimens taken from material in the form supplied by the producer of the aluminium alloy or from finished gas cylinders.

5.1.3 Some aluminium alloys are not compatible with certain gases and gas mixtures, for example, corrosive gases (*see* Annex A). The manufacturer shall use materials compatible with the intended gas service when the purchaser indicates the intended gas.

5.2 Thermal Treatments

5.2.1 *Heat Treatable Alloys (see Table 1, groups 1 and 3)*

The manufacturer shall specify on the prototype approval documentation, the solution heat treatment and artificial ageing temperatures and the minimum time for which the gas cylinders have been held at those temperatures. The medium used for quenching after solution heat treatment shall be identified.

5.2.2 *Non-Heat Treated Alloys (see Table 1, group 2)*

The manufacturer shall specify on the prototype testing documentation, the type of metal-forming operation carried out (extrusion, drawing, ironing, head forming, etc).

Unless the alloy is subjected to a temperature in excess of 400°C during the forming process, a stabilizing heat treatment shall be carried out at a temperature above 220°C, and the temperature and time shall be identified by the manufacturer.

5.2.3 Control of Specified Heat Treatment

During the heat treatment the manufacturer shall comply with the following tolerances:

a) Temperatures

Solution temperature	±10 °C
Artificial ageing temperature	±5 °C
Stabilizing temperature	±10 °C

b) Durations

Time gas cylinders actually spend at this temperature during treatment:

Solution treatment	±30 percent
Ageing treatment	±20 percent
Stabilizing treatment	±10 percent

5.3 Test Requirements

The material of the finished cylinders shall conform to **8**, **9** and **10**.

5.4 Failure to Meet Test Requirements

5.4.1 In the event of failure to meet test requirements, retesting or re-heat treatment and retesting shall be carried out as follows:

- If there is evidence of a fault in carrying out a test, or an error of measurement, a second test shall be performed, on the same gas cylinder if possible. If the result of this test is satisfactory, the first test shall be ignored.
- If the test has been carried out in a satisfactory manner and the failure is in a test representing the prototype or batch gas cylinders, the procedure detailed in either **5.4.2** or **5.4.3** shall be followed.
- If the test has been carried out in a satisfactory manner and the failure is in a test applied to every gas cylinder (**10**), then only those gas cylinders which fail the test, require re-heat treatment and retesting, provided the cause of the failure is well identified. If the failure is due to the heat treatment applied, then the failed cylinders shall be subject to the procedure given in **5.4.3**. If the failure is due to a cause other than the heat treatment applied, all defective gas cylinders shall be rejected.

5.4.2 Two further gas cylinders selected at random from the same batch shall be subjected to the tests specified in **9.1.3** (a) and **9.1.3** (b). If both cylinders meet the specified requirements, the batch shall be accepted. If any of the gas cylinder fails to meet the specified requirements, the batch shall

- be rejected, or
- be treated in accordance with **5.4.3**.

5.4.3 The batch of gas cylinders shall be reheated and two further gas cylinders shall be tested in accordance with **9.1.3** (a) and **9.1.3** (b). If both gas cylinders meet the specified requirements, the batch shall be accepted. If any of the gas cylinder fails to meet the specified requirements, the batch shall be rejected.

Table 1 Chemical Composition of Materials
(Clauses 5.1.1, 5.2.1, 5.2.2 and 9.2.2)

SI No.	Group	Type of Alloy (IAA Registered AA Designation)	Equivalent Designation as per IS 6051		Chemical Composition (percent by mass)											Others		Al
					Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Zr	Pb	Each	Total	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
i)	1	6351A	63430	Min	0.7	—	—	0.40	0.40	—	—	—	—	—	—	—	—	Remainder
ii)				Max	1.3	0.50	0.10	0.8	0.8	—	—	0.20	0.20	—	0.003 0	0.05	0.15	
iii)		6082A	64430	Min	0.7	—	—	0.40	0.60	—	—	—	—	—	—	—	—	Remainder
iv)				Max	1.3	0.50	0.10	1.0	1.2	0.25	—	0.20	0.10	—	0.003 0	0.05	0.15	
v)		6061A	65028	Min	0.40	—	0.15	—	0.8	0.04	—	—	—	—	—	—	—	Remainder
vi)				Max	0.8	0.7	0.40	0.15	1.2	0.35	—	0.25	0.15	—	0.003 0	0.05	0.15	
vii)	2	5283A	55300	Min	—	—	—	0.50	4.5	—	—	—	—	—	—	—	—	Remainder
viii)				Max	0.30	0.30	0.03	1.0	5.1	0.05	0.03	0.10	0.03	0.05	0.003 0	0.05	0.15	
ix)	3	7060	77258	Min	—	—	1.8	—	1.3	0.15	—	6.1	—	—	—	—	—	Remainder
x)				Max	0.15	0.20	2.6	0.20	2.1	0.25	—	7.5	0.05	0.05	0.003 0	0.05	0.15	
xi)		7032	N.A.	Min	—	—	1.7	—	1.5	0.15	—	5.5	—	—	—	—	—	Remainder
xii)				Max	0.10	0.12	2.3	0.05	2.5	0.25	0.05	6.5	0.1	0.05	0.003 0	0.05	0.15	
xiii)	4	2001	NA	Min	—	—	5.2	0.15	0.20	—	—	—	—	—	—	—	—	Remainder
xiv)				Max	0.20	0.20	6.0	0.50	0.45	0.10	0.05	0.10	0.20	0.05	0.003 0	0.05	0.15	
The bismuth content shall not exceed 0.003 0 percent (by mass).																		
NOTE — The above materials are used extensively throughout the world in preference to the alloy composition quoted in ISO 209. They are included in this Indian standard quoting the IAA registered designations but making reference to ISO 209 where it is considered applicable																		

5.4.4 For heat treatable alloys, where it can be established that the heat treatment was at fault for the failure of a test in **5.4.1** (c), the batch of gas cylinders may additionally be re-solution heat treated and/or aged one more time. Such cylinders may be submitted to the inspection body one more time for testing after the initial submission.

6 DESIGN

6.1 General Requirements

6.1.1 The calculation of the wall thickness of the pressure-containing parts shall be related to the yield stress (R_e) of the material.

6.1.2 For calculation purposes, the value of the yield stress (R_e) is limited to a maximum of $0.90R_g$ for seamless aluminium alloy gas cylinders.

6.1.3 The test pressure (P_h) upon which the calculation of wall-thickness is based shall be at least 1.5 times of the working pressure (P_w).

$$\text{Test Pressure } (P_h) = 1.5 \times \text{Working Pressure } (P_w)$$

6.2 Calculation of Cylindrical Wall Thickness

The guaranteed minimum thickness of the cylindrical shell (a) shall not be less than the thickness calculated using equations (1) and (2), and additionally condition (3) shall be satisfied:

$$a = \left(\frac{D}{2} \right) \left(1 - \sqrt{(10FR_e - \sqrt{3}P_h)/10FR_e} \right) \quad \dots\dots (1)$$

where

The value of F is the lesser of $0.65/(R_e/R_g)$ or 0.85

and R_e/R_g shall not exceed 0.90

The wall thickness shall also satisfy the relationship:

$$a \geq \frac{D}{100} + 1 \text{ mm} \quad \dots\dots (2)$$

With an absolute minimum of 1.5 mm

The burst ratio shall be satisfied by test. The following condition shall be met:

$$P_b/P_h \geq 1.6 \quad \dots\dots(3)$$

When choosing the minimum guaranteed value of the thickness of the cylindrical shell, a' , the manufacturer shall ensure that the thickness is sufficient to satisfy both the calculations and the required verification testing.

6.3 Design of Ends (Heads and Bases)

6.3.1 The thickness and shape of the base and head of the cylinders shall be such as to meet the

requirements of the tests laid down in **9.4** (hydraulic burst test) and **8.2.3** (pressure cycling test).

In order to achieve satisfactory stress distribution, the gas cylinder wall thickness shall increase progressively in the transition zone between the cylindrical shell and the ends, particularly the base, for example, typical shapes of convex heads and base ends are shown in Fig. 1.

6.3.2 The thickness at any part of the base shall be not less than the guaranteed minimum wall thickness of the cylindrical part. The base shall have a hemispherical, tori spherical or semi-ellipsoidal profile.

6.3.3 The inside crown radius r_i should not be greater than $1.2 \times$ the inside diameter of the shell, and the knuckle radius r should be not less than 10 percent of the inside diameter of the shell.

6.3.4 Where above conditions are not fulfilled, the cylinder manufacturer shall prove by the prototype tests as required in **8.2** that the design is satisfactory.

6.4 Neck Design

6.4.1 The external diameter and thickness of the formed neck end of the gas cylinder shall be adequate for the stresses resulting from the fitting of the valve to the gas cylinder. The stresses can vary according to the thread diameter, its form and the sealant used in fitting the valve. The requirements specified in IS 3224 shall not be exceeded, since this could result in permanent damage to the gas cylinder.

6.4.2 In establishing the minimum thickness, consideration shall be given to obtaining a thickness of the wall in the gas cylinder neck that will prevent permanent expansion of the neck during the initial and subsequent fittings of the valve into the gas cylinder.

In specific cases (for example, very thin walled cylinders), where the stresses resulting from the initial and subsequent fittings of the valve to the gas cylinder cannot be supported by the neck itself, the neck maybe designed with reinforcement, such as a neck ring or shrunk on collar, provided the reinforcement material and fitment dimensions are clearly specified by the manufacturer and this configuration is part of the type approval procedure.

6.4.3 Gas cylinders maybe designed with one or two openings which shall be along the central gas cylinder axis.

6.5 Foot-rings

When a foot-ring is provided, it shall be sufficiently strong and made of material compatible with that of

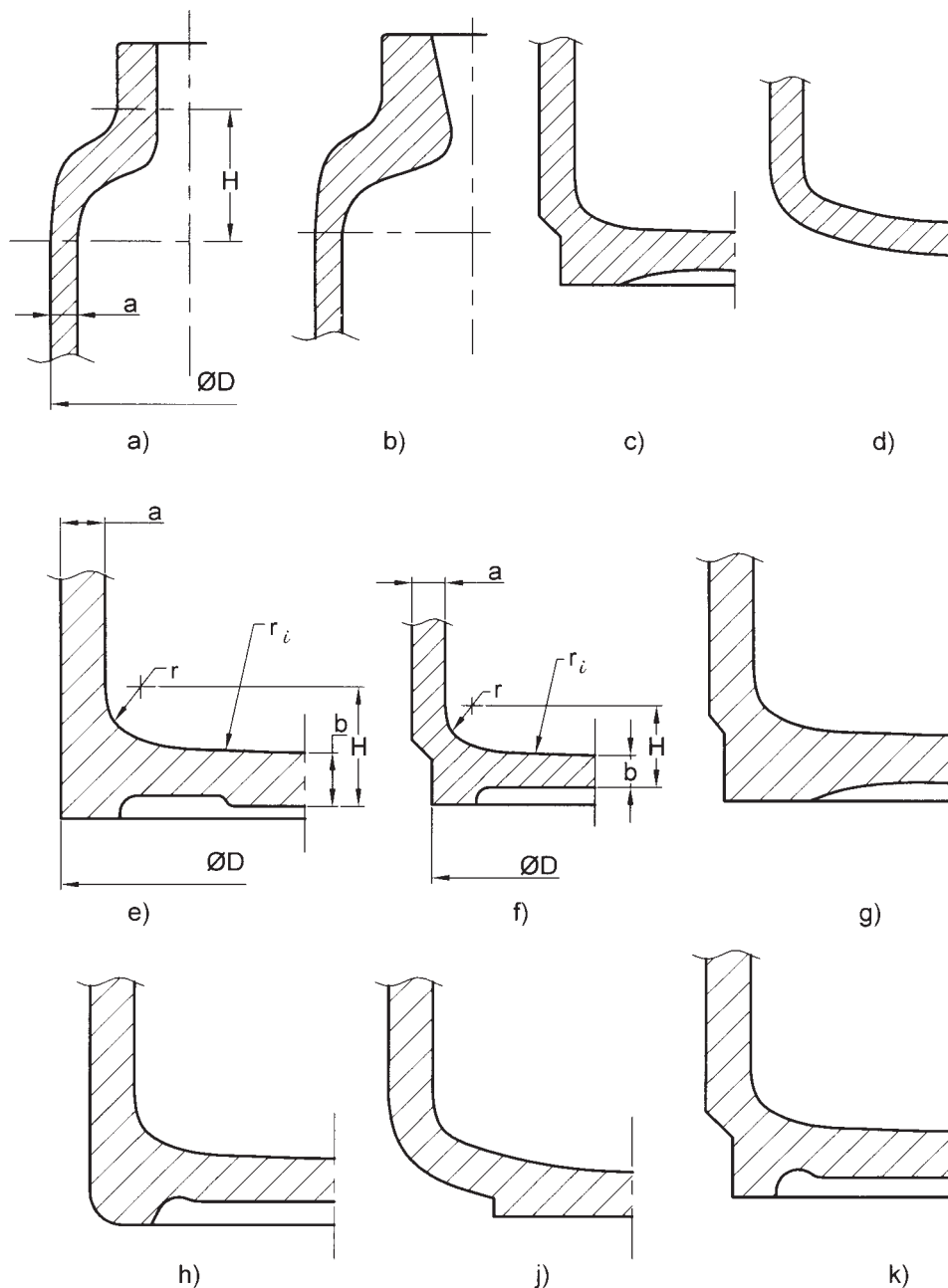


FIG. 1 TYPICAL ENDS

the gas cylinder. The shape should preferably be cylindrical and shall give the cylinder sufficient stability. The foot-ring shall be secured to the cylinder by a method other than welding, brazing or soldering. In order to prevent ingress of water, any gaps which may form water traps shall be sealed by a method other than welding, brazing or soldering.

6.6 Neck-rings

When a neck-ring is provided, it shall be sufficiently strong and made of material compatible with that of the cylinder, and shall be securely attached by a method other than welding, brazing or soldering.

The manufacturer shall ensure that the axial load to remove the neck-ring is greater than 10 times the weight of the empty cylinder but not less than a 1 000 N and that the minimum torque required to rotate the neck-ring is greater than 100 Nm.

6.7 Design Drawing

A fully dimensioned drawing (including tolerance) shall be supplied which includes the specification of the material, details of mechanical properties, neck thread water capacities, corresponding length and weight of cylinder, chemical composition and number of this standard.

6.8 Water Capacity

The manufacturer shall check and record the water capacity of each cylinder in order to ensure compliance to the standard.

- a) For cylinders of water capacity up to and including 20 litre = + 10.0 percent and – 0 percent subject to a maximum of 1 litre; and
- b) For cylinders of water capacity exceeding 20 litre = + 5 percent and – 0 percent.

6.9 High Strength and/or Low-Elongation Gas Cylinder Designs

Requirement for these designs are given in Annex B.

7 CONSTRUCTIONS AND WORKMANSHIP

7.1 General

The gas cylinder shall be produced by

- a) cold or hot extrusion from cast (*see 7.3*) or extruded or rolled billet;
- b) cold or hot extrusion, followed by cold drawing from cast (*see 7.3*) or extruded or rolled billet;
- c) cupping, flow forming, spinning and cold drawing from sheet or plate;
- d) open necking at both ends of an extruded or cold-drawn tube (*see Fig. 2*);
- e) Non-welding techniques; and
- f) Plugging to correct manufacturing defects is not permitted.

7.2 Welding

Welding of seamless aluminium and aluminium alloy gas cylinders is not permitted under any circumstances.

7.3 Neck Forming

The neck shall be formed by an appropriate method, for example, forging, swaging or spinning. Prior to and/or after the closing-in operation, all significant remnants of the as-cast structure of the open end of the shell shall be removed.

When heat has to be applied to form the cylinder's neck/shoulder, uniform heat distribution shall be achieved prior to the forming operation, for example, by means of induction heating. This heat distribution shall be achieved independent of the process employed for the manufacture of the shell.

For 6 000 series alloys special precautions shall be taken to achieve a fine grain structure in the neck of the finished cylinder.

Regardless of the method used for the closing-in operation, the tools used for the head forming process shall facilitate metal flow and result in smooth surfaces of the cylinder, especially in the neck/shoulder /knuckle areas. There shall be no sudden contour changes or significant folds (*see 10.7*), which may act as stress raisers during the cylinder's eventual service conditions.

7.4 Wall Thickness

Each gas cylinder shall be examined at the time of production for thickness. The wall thickness at any point shall be not less than the minimum thickness specified.

7.5 Surface Imperfections and Defects

Each gas cylinder shall be examined at the time of production for internal and external surface imperfections and defects. The internal and external surfaces of the finished gas cylinder shall be free from defects that would adversely affect the safe working of the gas cylinder.

Such defects shall be removed by local dressing (where permitted) or the cylinder shall be condemned. The wall thickness of any dressed areas shall not be less than that of the minimum thickness specified in the design. Imperfections are subject to the requirements of **10.7**.

7.6 Neck Threads

The internal neck threads shall conform to IS 3224 or a recognized standard permitted by the statutory authority to permit the use of a corresponding valve thus minimizing neck stresses following the valve torquing operation. Internal neck threads shall be checked using gauges corresponding to the neck thread or by an alternative method agreed between the parties.

The thread shall be full form, clean cut, even and without chatter, answering to gauges and concentric with the axis of the cylinder. Particular care shall be taken to ensure that neck threads are accurately cut, are of full form and free from any sharp profiles, for example burrs.

7.7 Out-of-Roundness

The out-of-roundness of the cylindrical shell, that is the difference between the maximum and minimum outside diameters in the same cross-section, shall not exceed 2 percent of the mean of these diameters.

7.8 Exposure to Heat

Any exposure to heat after the heat treatment or stabilization treatment, if required as a part of the

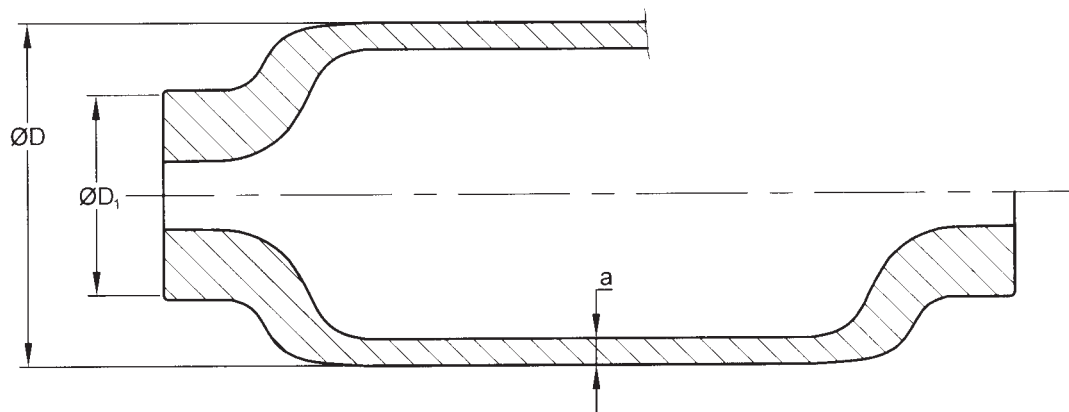


FIG. 2 NECKED END OF CYLINDER

manufacturing process, shall not modify the characteristics of the aluminium alloy used to the extent that the mechanical properties fall below the minimum guaranteed values. This shall be validated while setting up the manufacturing process. If such an exposure is part of the process, the hardness readings and sampling for all the tests shall be done after such exposure is applied.

7.9 Verticality

Deviation from vertical shall not exceed 10 mm/m length (see Fig. 3).

7.10 Stability

For a cylinder designed to stand on its base, the deviation from vertical shall be less than 1 percent of its height, and the outer diameter of the surface in contact with the ground shall be greater than 75 percent of the nominal outside diameter.

7.11 Straightness

The maximum deviation of the cylindrical part of the shell from a straight line shall not exceed 3 mm/m length (see Fig. 3).

7.12 Mean diameter

The mean external diameter shall not deviate from nominal design diameter by more than ± 1 percent or ± 1 mm whichever is the larger.

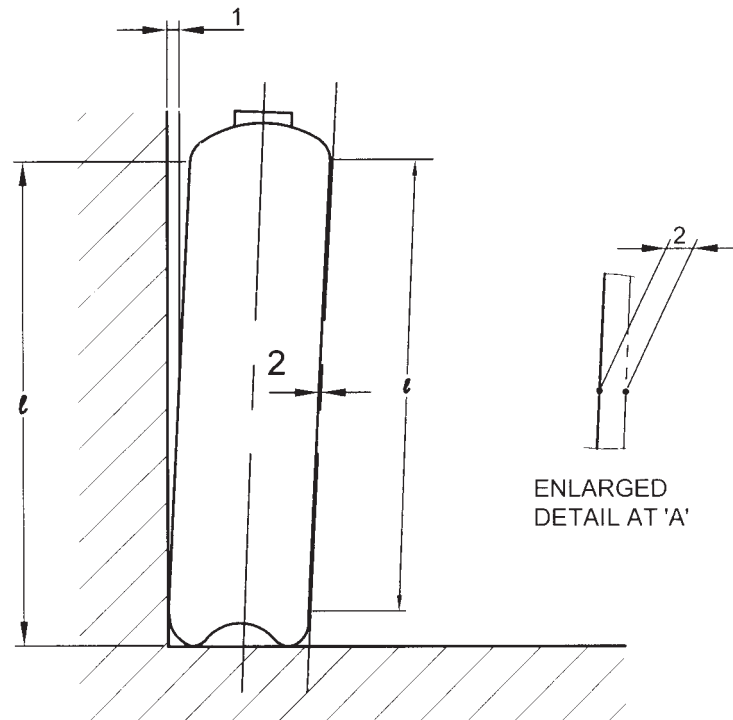
8 TYPE APPROVAL PROCEDURES

8.1 General Requirements

A technical specification for each new design of gas cylinder [or gas cylinder family as defined in (f)] including design drawing, design calculations, alloy details and heat treatment, shall be submitted by the manufacturer to the inspection body. The type approval tests detailed in 8.2 shall be carried out on each new design under the supervision of the inspection body.

A gas cylinder shall be considered to be of a new design compared with an existing approved design, when:

- a) It is manufactured in a different factory; or
- b) It is manufactured by a different process (this includes the case when major process changes are made during the production method, for example, a change in the neck forming method) (see 7.1); or
- c) It is manufactured from an alloy of different specified composition limits from that used in the original prototype tests; or
- d) It is given a different heat treatment that is outside the temperature ranges specified in 5.2.3; or
- e) The base profile and the base thickness have changed relative to the gas cylinder diameter and calculated minimum wall thickness; or
- f) The overall length of the gas cylinder has increased by more than 50 percent (gas cylinders with a length/diameter ratio less than three shall not be used as reference gas cylinders for any new design with this ratio greater than three); or
- g) The nominal outside diameter has changed; or
- h) The design wall thickness has changed; or
- j) The hydraulic test pressure has been increased (where a cylinder is to be used for lower-pressure duty than that for which design approval has been given, it shall not be deemed to be a new design); or
- k) The guaranteed minimum yield stress (R_e) and/or the guaranteed minimum tensile strength (R_g) have changed.



Key

- 1 — $0.01 \text{ maximum} \times l$ (see 7.9)
 2 — $0.01 \text{ maximum} \times l$ (see 7.11)

FIG. 3 ILLUSTRATION OF DEVIATION OF CYLINDRICAL PART OF SHELL FROM A STRAIGHT LINE AND FROM VERTICAL

8.2 Prototype Tests

8.2.1 General

A minimum of 50 gas cylinders which are guaranteed by the manufacturer to be representative of the new design, heat treated, not more than 10 percent the minimum heat treatment duration as required in 5.2, shall be made available for prototype testing. If the gas cylinders are likely to experience exposure to heat in further processing (for example heating for painting) (see 7.8), testing shall be carried out on representative gas cylinders.

However, if the total number of cylinders required is less than 50, enough gas cylinders shall be made to complete the prototype tests required, in addition to the production quantity, but in this case the approval validity is limited to this particular production batch.

8.2.2 Inspection

In the course of the type approval process, the inspector shall select the necessary cylinders for testing and then proceed as follows:

- a) The inspection body shall verify that:
 - 1) the material conforms to 5;
 - 2) the design conforms to the requirements of 6;
 - 3) the thicknesses of the walls and ends on two of the gas cylinders taken for tests meet the requirements of 6.2, 6.3 and 6.4. The measurements being taken on three transverse sections of the cylindrical part and over the whole of a longitudinal section of the base and the head;
 - 4) the requirements of 6.5, 6.6, 6.8 and 7.2 to 7.12 shall be complied with for all cylinders selected by the inspection body; and
 - 5) the material meets the requirements of the inter-crystalline and stress corrosion tests specified in Annex C. This test is not applicable if the outside diameter has changed by less than 20 percent.
 - 6) the sustained load cracking test has been completed satisfactorily in accordance

NOTE — This is a material qualification test (*see D-2*) and not a prototype test.

- b) The inspection body shall then Supervise the following tests on the cylinders selected:
- 1) The tests specified in **9.1.3** (a) (mechanical testing) on two gas cylinders, the test pieces being identifiable with the batch;
 - 2) The tests specified in **9.1.3** (b) (hydraulic burst test) on two gas cylinders, the cylinders bearing representative stamp markings; and
 - 3) The tests specified in **8.2.3** (pressure cycling test) on three gas cylinders, the gas cylinders bearing representative stamp markings.

8.2.3 Pressure Cycling Test

This test shall be carried out with a non-corrosive liquid subjecting the cylinders to successive reversals at an upper cyclic pressure which is equal to the hydraulic test pressure (P_h). The cylinders shall withstand 12 000 cycles without failure.

For gas cylinders with hydraulic test pressure (P_h) > 450 bar, the upper cyclic pressure may be reduced to two-thirds of the test pressure. In this case the cylinders shall withstand 80 000 cycles without failure.

The value of the lower cyclic pressure shall not exceed 10 percent of the upper cyclic pressure, but with an absolute maximum of 30 bar.

The gas cylinder shall actually experience the maximum and minimum cyclic pressures during the test.

The frequency of reversals of pressure shall not exceed 0.25 Hz (15 cycles/min). The temperature measured on the outside surface of the cylinder shall not exceed 50°C during the test.

After the test the gas cylinder bases shall be sectioned in order to measure the thickness and to ensure that this thickness is sufficiently close to the minimum thickness prescribed in the design and shall be within the usual production tolerances. In any case, the actual base thickness shall not exceed the value as specified on the drawing, by more than 15 percent.

The test shall be considered satisfactory if the gas cylinder attains the required number of cycles without developing a leak.

8.2.4 Test Requirements for High-strength and/or Low-elongation Gas Cylinder Designs

High-strength and/or low-elongation gas cylinder

designs shall be subject to the requirements of Annex B.

8.3 Type Approval Certificate

If the results of the checks according to **8.2** are satisfactory, the inspection body shall issue a type approval certificate, a typical example of which is given in Annex E.

9 BATCH TESTS

9.1 General Requirements

9.1.1 All tests for checking the quality of the gas cylinder shall be carried out on material from finished gas cylinders. Gas cylinders for mechanical and burst testing need not have been pressure tested.

For the purpose of batch testing, the manufacturer shall provide the inspector with:

- a) the type approval certificate.
- b) the certificates stating the cast analyses of the alloy supplied for the construction of the gas cylinders.
- c) a means of identifying the cast of the material from which each gas cylinder was made.
- d) a statement of the manufacturing processes utilized as specified in **7.1** and **7.2** and the relevant documentation relating to the heat and mechanical treatment.
- e) a list of the cylinders, stating serial numbers and stamp markings as required.
- f) confirmation that threads have been checked properly in accordance with gauging requirements. The gauges to be used shall be specified (for example IS 15894, IS 9122, IS 7202 etc).
- g) verification that the water capacity conforming to the design drawing.

9.1.2 During batch testing, the Inspection Body shall select the gas cylinders necessary for testing and then proceed as follows:

- a) The Inspection Body shall ascertain that the type approval certificate has been obtained and that the gas cylinders conform to it.
- b) The Inspection Body shall then check that the markings are in accordance with the design specification.
- c) The Inspection Body shall also check whether the requirements set out in **5**, **6** and **7** have been met and, in particular, check by an external and, if physically possible, internal visual inspection of the gas cylinders whether their construction and the checks carried out by the manufacturer in accordance with **6.5**, **6.6**, **7.2** to **7.12** are satisfactory. This visual

6.6, 7.2 to 7.12 are satisfactory. This visual examination shall cover at least 10 percent of the gas cylinders submitted. If an internal unaided visual examination be physically impossible, an alternative inspection method shall be agreed between the manufacturer and the Inspection Body. At least 10 percent of the batch shall be checked by this method.

- d) However, if a gas cylinder not meeting the above requirements is found, then all of the gas cylinders shall be inspected.
- e) The Inspection Body shall witness the tests and verify that the results of the tests specified in 9.1.3 (a) (mechanical testing) and 9.1.3 (b) (hydraulic burst testing) are satisfactory. Where alternative tests are permitted, the purchaser and manufacturer shall agree which tests are to be carried out.
- f) The Inspection Body shall check whether the information supplied by the manufacturer referred to in 9.1.1 is correct (random checks shall be carried out).
- g) Finally, the Inspection Body shall assess the results of the hardness testing specified in 10.3.

9.1.3 The following tests shall be carried out on each batch of gas cylinders:

- a) On one gas cylinder:
 - 1) One tensile test in the longitudinal direction (*see 9.2*);

- 2) Two bend tests in a circumferential direction (*see 9.3.1*) or a flattening test (*see 9.3.2*).

The location of the test specimens shall be in accordance with Fig. 4.

- b) On a second gas cylinder:

- 1) One hydraulic burst test (*see 9.4*).

9.2 Tensile Test

9.2.1 The tensile test shall be carried out in accordance with IS 1608 on a test specimen which is shaped in accordance with Fig. 5 and with a gauge length given by $L_0 = 5.65\sqrt{S_0}$. The two faces of the test specimen representing the inside and the outside surfaces of the gas cylinder shall not be machined.

9.2.2 With regard to the heat-treatable alloys referred to in Table 1, the percentage elongation after fracture, A , shall be not less than 12 percent, except for AA 2001 which is covered in Annex B.

With regard to the non-heat-treatable alloys referred in Table 1, the elongation after fracture shall not be less than 12 percent when the test is carried out on a single test specimen taken from the gas cylinder wall. The tensile test may also be carried out on four test specimens distributed uniformly throughout the gas cylinder wall. The results shall be as follows:

- a) No individual value shall be less than 11 percent; and
- b) The average of the results from all the test specimens shall be at least 12 percent.

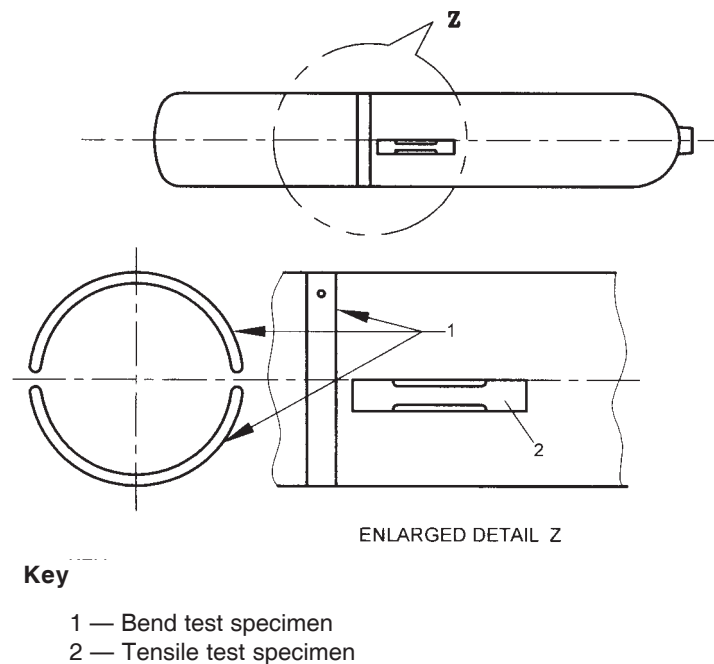
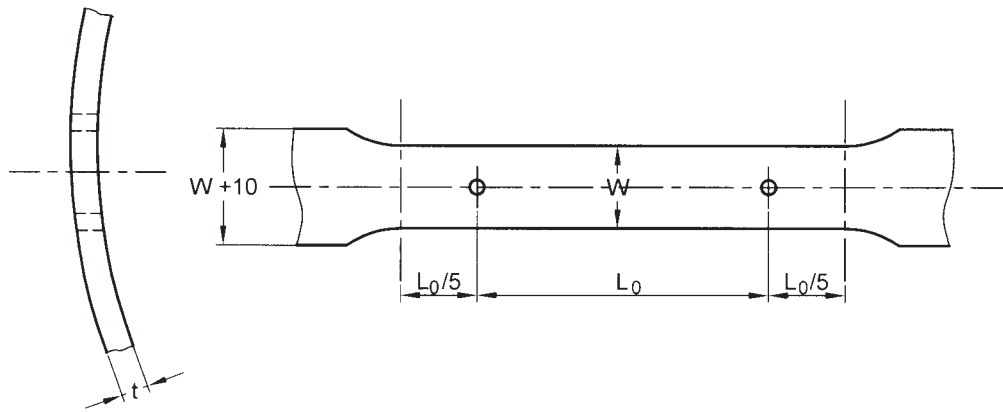


FIG. 4 LOCATION OF TEST SPECIMEN



NOTE — Test specimen dimensions when $t > 3$ mm
 $W \leq 4t$
 $W < D/8$

FIG. 5 TENSILE TEST SPECIMEN

9.3 Bend Test and Flattening Test

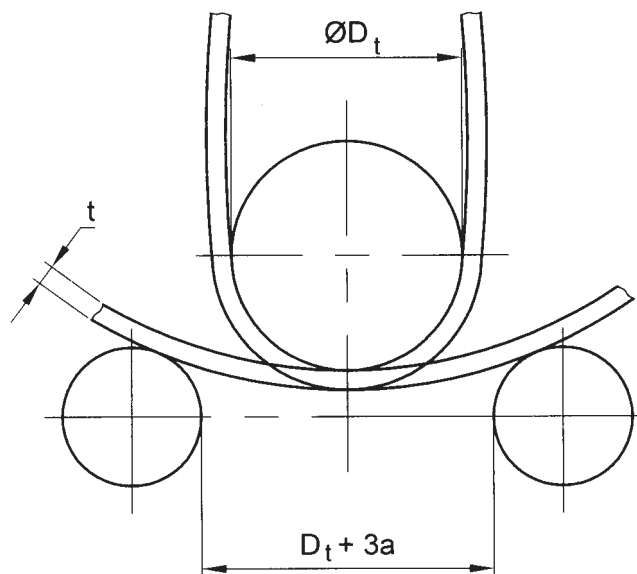
9.3.1 Bend Test

9.3.1.1 The bend test shall be carried out in accordance with IS 1599 on two test specimens obtained by cutting either one or two rings of width 25 mm or $3t$ whichever is the greater, into four equal parts. The two test specimens shall be taken from the parts that were 180° apart. Each test specimen shall be of sufficient length to permit the bend test to be carried out correctly. Only the edges of each strip may be machined.

9.3.1.2 The test specimen shall not crack when bent inwards around the former until the inside surfaces are no further apart than the diameter of the former (see Fig. 6).

9.3.1.3 The diameter of the former (D_f) shall be established from Table 2 for the relevant actual tensile strength (R_m) as given in Table 2.

$$D_f = n \times \text{test piece thickness } (t)$$



a = Calculated Minimum Thickness

FIG. 6 ILLUSTRATION OF BEND TEST

Table 2 Bend Test and Flattening Test Requirement

(Clauses 4, 9.3.1.3, 9.3.2.2 and 9.3.2.3)

Sl No.	Actual Tensile Strength, R_m MPa	Value of n for Bend Test and Flattening Test	Value of u for Flattening Test ¹⁾
(1)	(2)	(3)	(4)
i)	$R_m \geq 325$	6	10
ii)	$325 < R_m \leq 440$	7	12
iii)	$R_m > 440$	8	15

¹⁾ Distance between knife edges at end of test = $u \times t_m$, where t_m is the average gas cylinder wall thickness at the position of test.

9.3.2 Flattening Test

9.3.2.1 The flattening test shall be performed on one gas cylinder selected from each batch after heat treatment.

9.3.2.2 The test gas cylinder shall be flattened between wedge shaped knife edges with a 60° included angle. The maximum radius of the knife edges shall be established from Table 2 for

the relevant actual tensile strength (R_m) given in Table 2.

$$\text{Maximum radius} = n \times t_m$$

where t_m is the average gas cylinder wall thickness at the position of test.

The length of the knife edges shall not be less than width of the flattened gas cylinder. The longitudinal axis of the gas cylinder shall be at approximately 90° to the knife edges.

9.3.2.3 The test gas cylinder shall be flattened until the distance between the knife edges is in accordance with Table 2. The flattened gas cylinder shall remain visually un-cracked.

9.4 Hydraulic Bursting Test**9.4.1 Test Installation**

The test equipment shall be capable of operation in accordance with the test conditions specified in 9.4.2 and of accurately producing the information required by 9.4.3. A typical hydraulic bursting test installation is illustrated in Fig. 7.

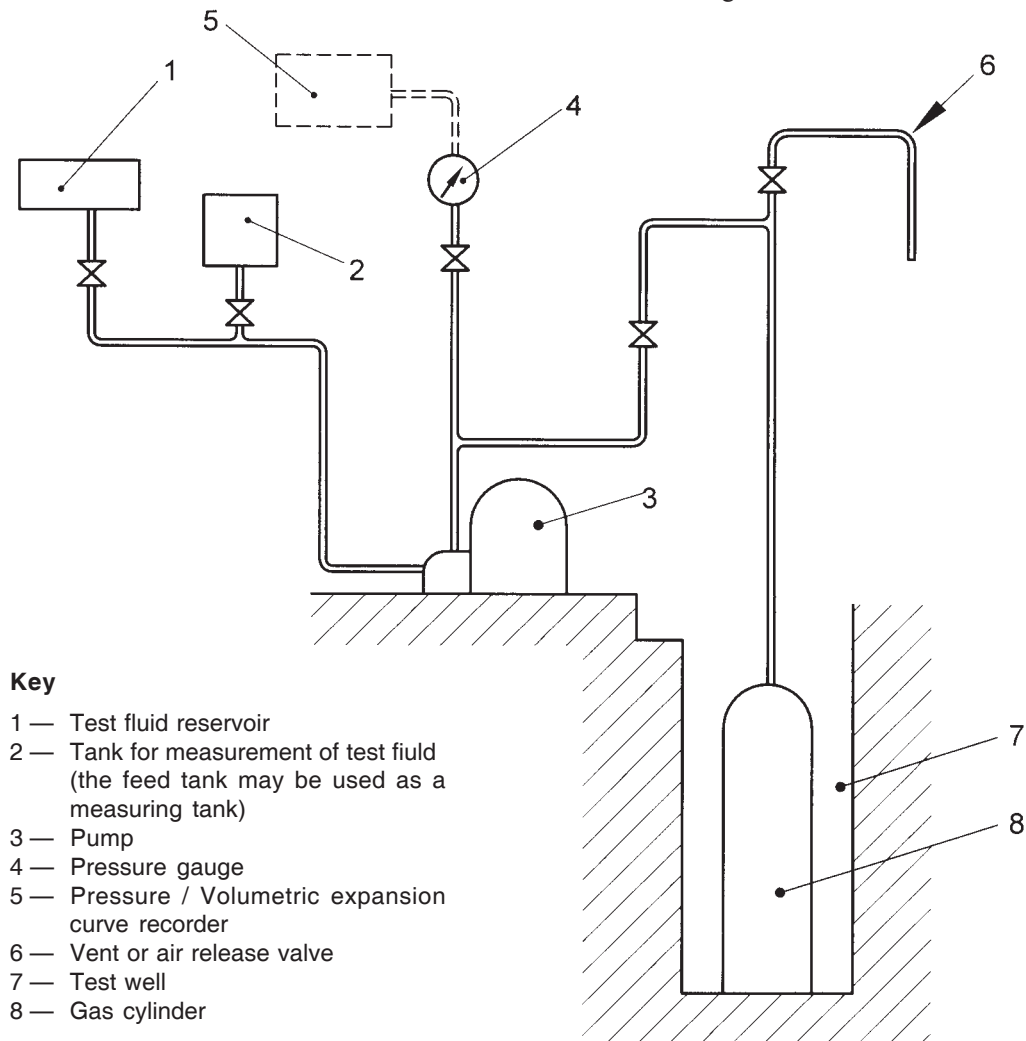


FIG. 7 TYPICAL HYDRAULIC BURST TEST INSTALLATION

9.4.2 Test Conditions

Because the gas cylinder and test equipment are being filled with water, care shall be taken to ensure that no air is trapped in the circuit by operating the hydraulic pump until water is discharged from the vent or air release valve.

During the test, pressurization shall be carried out in two successive stages:

- a) in the first stage, the pressure shall be increased at a rate of not more than 5 bar/s upto a pressure value corresponding to the initiation of plastic deformation.
- b) in the second stage, the pump discharge rate shall be maintained at as constant a level as is possible, until the gas cylinder bursts.

9.4.3 Interpretation of Test

9.4.3.1 The interpretation of the burst test shall involve:

- a) examination of pressure/time curve or pressure/volume-of-water-used curve, to permit determination of the pressure at which plastic deformation of the gas cylinder commences, together with the bursting pressure and volumetric expansion of the gas cylinder during the test.
- b) examination of the burst tear and of the shape of its edges.

9.4.3.2 For the results of a bursting test to be considered satisfactory, the following requirements shall be met.

- a) The observed yield pressure P_y shall be equal to or greater than $1/F$ times the test pressure, that is:

$$P_y \geq \frac{1}{F} \times P_h$$

- b) The actual burst pressure P_b shall be greater than or equal to 1.6 times the test pressure, that is:

$$P_b \geq 1.6 \times P_h$$

9.4.3.3 The cylinder shall remain in one piece and shall not fragment.

9.4.3.4 The main tear shall not be of a brittle type, that is, the edges of the fracture shall not be radial but shall be sloping in relation to a diametral plane. The tear shall not reveal a significant defect in the metal.

9.4.3.5 The fracture shall be acceptable only if it conforms to one of the following descriptions:

- a) for gas cylinders of actual wall thickness 13 mm or less:
 - 1) The greater part of the fracture shall be longitudinal except for cylinders where the ratio of length to outside diameter is less than 3:1;
 - 2) At each end of the fracture, no more than two branches (*see L' and L'' in Fig. 8*) shall be allowed and only if the shorter branch, which may be at either end, is less than 20 mm long;
 - 3) The fracture shall not extend more than 90° around the circumference on either side of its main part (*see d' and d'' in Fig. 8*); and
 - 4) The fracture shall not extend into those parts of the gas cylinder of thickness more than $1.5 \times$ the maximum thickness measured halfway up the gas cylinder (for gas cylinders with convex bases, the fracture shall not reach the centre of the gas cylinder base).

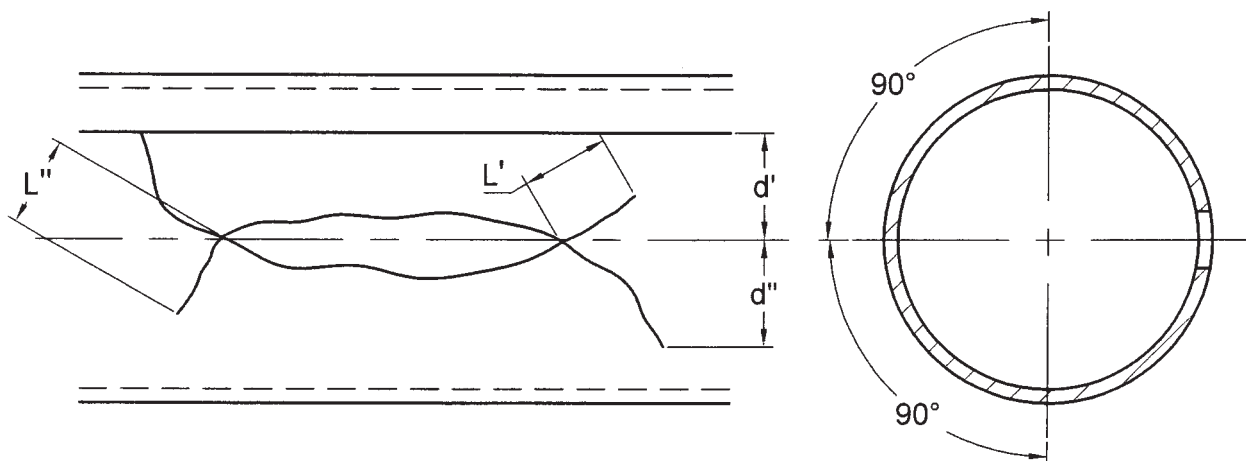


FIG. 8 ILLUSTRATION OF CIRCUMFERENTIAL DEVELOPMENT OF FRACTURE

- b) For cylinders of actual wall thickness over 13 mm the greater part of the fracture shall be longitudinal.

9.5 Test Requirements for High-Strength and/or Low-Elongation Gas Cylinder Designs

High-strength and/or low-elongation gas cylinder designs shall be subject to the requirements of Annex B.

10 TESTS ON EVERY CYLINDER

10.1 General

At the time of production, the examinations required in 7.3 and 7.4 shall be performed on each cylinder. Following final heat treatment (*see* 5.2), all gas cylinders, except those selected for testing under 9, shall be subjected to the following tests:

- a) Hydraulic volumetric-expansion test in accordance with 10.2 (Additional guidance on these tests methods and details of equipment calibration and maintenance can be found in IS 16017).
- b) A hardness test in accordance with 10.3.
- c) A leakage test in accordance with 10.4.
- d) An examination for neck folds in accordance with 10.5.
- e) All the gas cylinders shall be examined for manufacturing defects (*see* Annex F).

10.2 Hydraulic Test (Volumetric Expansion Test)

The water pressure in the gas cylinder shall be increased at a controlled rate until the test pressure, P_h , is reached. The gas cylinder shall remain under pressure P_h for at least 30s and the total volumetric expansion measured. The pressure shall then be released and the volumetric expansion re-measured (*see* IS 5844).

The gas cylinder shall be rejected if it shows a permanent expansion (that is, volumetric expansion after the pressure has been released) in excess of 5 percent of the total volumetric expansion measured at the test pressure, P_h .

The total and permanent expansion readings shall be recorded, together with the corresponding serial number of each gas cylinder tested, so that the elastic expansion (that is, total expansion less permanent expansion) under the test pressure can be established for each gas cylinder.

10.3 Hardness Test

A hardness test in accordance with IS 1500 (Brinell), IS 1586 (Rockwell B) shall be carried out by the manufacturer. The hardness values thus determined

shall be within the limits specified by the gas cylinder manufacturer for the material and manufacturing route, dependent upon the final treatment used for the production of the gas cylinder. The values may be expressed in Brinell, Rockwell B or other, equivalent units.

10.4 Leakage Testing

The manufacturer shall employ such manufacturing techniques and apply such tests as will demonstrate to the satisfaction of the Inspection Body that the gas cylinders do not leak. This test shall be conducted at working pressure (P_w).

10.5 Examination for Neck Folds

Each gas cylinder shall be examined for neck folds by a suitable means (for example, dentist mirror, scope, tactile, ultrasonic, etc). Severe folds might adversely affect the performance of the gas cylinder or the integrity of the gas cylinder. To assess the effect of any severe folds in the gas cylinder, gas cylinders with such folds shall be used for batch pressure-cycling and burst tests. In addition, gas cylinders with folds that exceed two continuous threads shall be condemned.

Folds that do not adversely affect the performance or the integrity of the gas cylinder may be machined until the lines are no longer visible (that is, repaired). Gas cylinders with folds running into two or less threads (as shown on the left-hand side of Fig. 9) may be repaired. If a gas cylinder is repaired in this way, the thread shall still meet the minimum requirements for length and number as per the relevant standard. In addition, the remaining thickness of the machined area and the thread's characteristics shall be at least those required to pass all necessary testing. The whole internal shoulder area shall be re-inspected to verify that folding or its lines have been removed.

10.6 Cylinder Marking

10.6.1 The marking shall be made on the areas in the formed neck where the thickness of metal is greater than the design minimum and where it is adequate for marking to be carried out. Each cylinder shall be permanently stamped with the following:

- a) Serial number, identification of manufacturer and year of manufacture;
- b) Number of this standard, IS 15660;
- c) Test pressure (in bar or kgf/cm²) and date of the hydrostatic stretch test (such as 03/15 for March 2015);
- d) Tare weight, in kg (except in case of dissolved gas);

- e) Design minimum water capacity of the cylinder, in litres;
- f) Inspector's official mark;
- g) Minimum guaranteed wall thickness of the cylindrical shell, in mm;
- h) Symbol for heat treatment, Q&T;
- j) Filling pressure in bar or kgf/cm² at 15°C in case of permanent gases and filling ratio in case of high pressure liquefiable gases;
- k) Name or chemical symbol of the gas for which cylinder is to be used; and
- m) Identification of cylinder thread, codes as per IS 3224 or any approved standard.

10.6.2 The character in marking shall be at least 5 mm in height. The height may be reduced for cylinder below 140 mm diameter. In no case the characters shall be less than 2.5 mm in height. The indentation shall not be of excessive depth.

10.6.3 The marking shall have small radii at changes of section to avoid the formation of sharp edges in the marking.

10.7 Aluminium Alloy Gas Cylinder Surface Features at Time of Manufacture

10.7.1 Requirements

At the time of manufacture, finished gas cylinders shall have no feature which adversely affects gas cylinder performance or integrity (*see 7.4* and specific unacceptable imperfections in other sub-clauses of 7 and in this sub-clause). Such features are considered to be defects.

At the time of manufacture, finished gas cylinders shall have no surface imperfections which would be considered to be unacceptable according to IS 16017.

The integrity and performance of gas cylinders with questionable features identified by the Inspection Body shall be verified by testing samples from the batch in accordance with the test procedures and criteria in this standard. The batch shall be condemned if the tests show unacceptable results and deemed acceptable, if the tests show acceptable results.

Surface imperfections may be dressed or repaired provided the gas cylinder wall thickness meets or exceeds the thickness required by this standard.

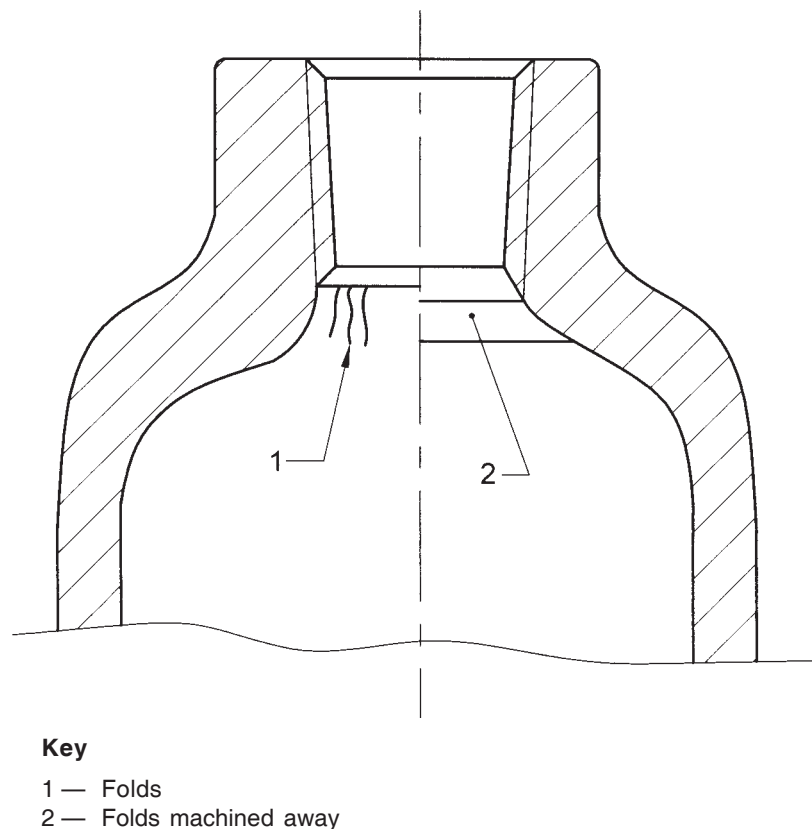


FIG. 9 ILLUSTRATION OF GAS CYLINDERS NECK FOLDS BEFORE AND AFTER MACHINING

10.7.2 Imperfection Considerations

Annex F describes gas cylinder surface imperfections and gives the criteria by which they may be assessed. Those imperfections which are acceptable should be agreed upon between the manufacturer and purchaser. Purchasers may specify surface imperfection criteria such as those listed in Annex F or establish their own criteria, provided such criteria do not conflict with the requirements specified in 10.7.1.

11 CERTIFICATION

Each satisfactory batch of gas cylinders shall be covered by a certificate, signed by the Inspecting Authority's representative, to the effect that the gas cylinders meet the requirements of this standard in all respects. An example of a suitably worded certificate is given in Annex G.

Copies of the certificate shall be issued to the manufacturer. The original certificate shall be retained by the inspection body and the manufacturer. Two copies shall be retained by the manufacturer in accordance with the Regulations of the relevant statutory Authority.

12 BIS CERTIFICATION MARKING

The cylinder may also be marked with the standard mark

12.1 The use of standard mark is governed by the provision of *Bureau of Indian standard act*, 1986 and the rules and Regulation made there under. The details of the conditions under which the license for the use of the standard mark may be granted to the manufactures or producers may be obtained from Bureau of Indian standard

13 COLOUR IDENTIFICATION

The cylinder shall be painted externally on shoulder in accordance with color scheme as applicable in accordance with IS 4379, IS 3933, IS 15683.

13.1 Cylinder manufactured for export shall be painted externally as agreed to between the purchaser and the manufacturer.

14 Before being dispatched from the manufacturer's works, all cylinders shall be thoroughly cleaned and dried and shall be made free from any foreign particles.

15 RECORDS

Records shall be kept of all the tests made at the cylinder manufacturer's works. Copies shall be forwarded to the inspecting authority. Certificate as per Annex G shall be issued to the purchaser.

ANNEX A

(Clause 5.1.3)

GASES NOT TO BE CONTAINED IN ALUMINIUM ALLOY CYLINDERS

A-1 Subject to the exceptions stated, the following, gases shall not be contained in aluminium alloy, cylinders. Certain of these gases may however be contained in aluminium alloy cylinders in small chloride, quantities as components of gas mixtures. Approval for such use shall be obtained from the statutory authority.

- | | |
|---|---|
| <ul style="list-style-type: none"> a) Acetylene, b) Boron trifluoride, c) Bromotrifluoroethylene, d) Carbonyl chloride, e) Chlorine, | <ul style="list-style-type: none"> f) Chlorine trifluoride, g) Cyanogen, h) Fluorine, j) Hydrogen bromide, k) Hydrogen chloride, m) Hydrogen fluoride, n) Methyl bromide, and p) Methyl chloride. |
|---|---|

NOTE— This is not an exhaustive list, for other gases *see* IS/ISO 11114-1.

ANNEX B

(Clauses 6.9, 8.2.4, 9.2.2 and 9.5)

SPECIFIC REQUIREMENTS FOR GAS CYLINDERS MADE OF HIGH-STRENGTH
AND/OR LOW-ELONGATION ALUMINIUM ALLOY**B-1 FIELD OF APPLICATION**

This Annex applies to aluminium alloys of design yield strength greater than 380 MPa and those alloys for which the elongation after fracture is less than 12 percent. Alloys of lower elongation after fracture which have higher strength (compared to 5 000-series or 6 000-series alloys) may be accepted, provided adequate fracture toughness and an adequate resistance to crack propagation under a cycling stress are demonstrated.

This requires up to two types of test, both of which use an artificial flaw produced by machining.

One test, known as the leak before burst (LBB) test, aims at establishing that, when the gas cylinder is cycled or burst at a pressure of at least $2/3 P_h$, the critical defect size for which rupture would occur by leaking (and not by bursting) is above a specified value.

The other test, if applicable, aims at establishing that the residual cycling life at P_h of a gas cylinder bearing a specified defect remains above a specified value. This test is known as the flawed gas cylinder cycling (FCC) test.

Clause **B-3** and **B-4** specify the test procedures. **B-5** specifies the frequency of testing. **B-6** specifies additional manufacturing requirements for alloy 2 001. The applicable elongation after fracture requirements are also specified.

NOTE — A similar approach has been used for gas cylinders made of high-strength steels (see ISO 9809-2).

B-2 GENERAL REQUIREMENTS

All alloys of design yield strength greater than 380 MPa shall be prototype-tested with the LBB test.

If the elongation after fracture is below 12 percent at all design yield strength levels, then both the LBB and the FCC tests described below shall be performed.

Any design with a diameter and service pressure equal to or less than the diameter and service pressure of a gas cylinder for which LBB and/or FCC testing has already been carried out does not require a repetition of the LBB or FCC test.

B-3 LEAK BEFORE BURST TEST (LBB TEST)**B-3.1 Flaw Production Procedure**

The test shall be carried out on two gas cylinders. One flaw shall be machined on each gas cylinder to be tested. The flaw shall be machined longitudinally. It shall be located approximately at the mid-length of the cylindrical part of the gas cylinder, and at the point where the minimum wall thickness of this mid-section is recorded (based on four measurements equally spaced around the circumference).

The flaw length, l_o , shall be the overall length of the cut and shall be at least equal to $4a$, where a is the calculated minimum thickness of the cylindrical shell (see Fig. 10).

The cutter used to machine the flaw shall be approximately 12.5 mm thick, with an angle of 45° to 60° and a tip radius, r_c , of (0.25 ± 0.05) mm. The cutter diameter ($=2R_c$, where R_c is the radius of curvature of the end of the flaw as shown in Fig. 10) shall be 20 mm for gas cylinders with a nominal outside diameter, D , not greater than 140 mm and 30 mm for gas cylinders with D greater than 140 mm. A standard computer numerical controlled (CNC) cutter is recommended.

Larger cutter diameter, or other means of machining which do not affect the properties of the material, maybe used when so required to achieve an appropriate flaw depth in thick-walled gas cylinders.

The depth of the flaw shall be equal to at least 60 percent of the actual wall thickness, t , of the gas cylinder at the flaw location.

The cutter should be sharpened regularly to ensure that the tip radius meets the requirements.

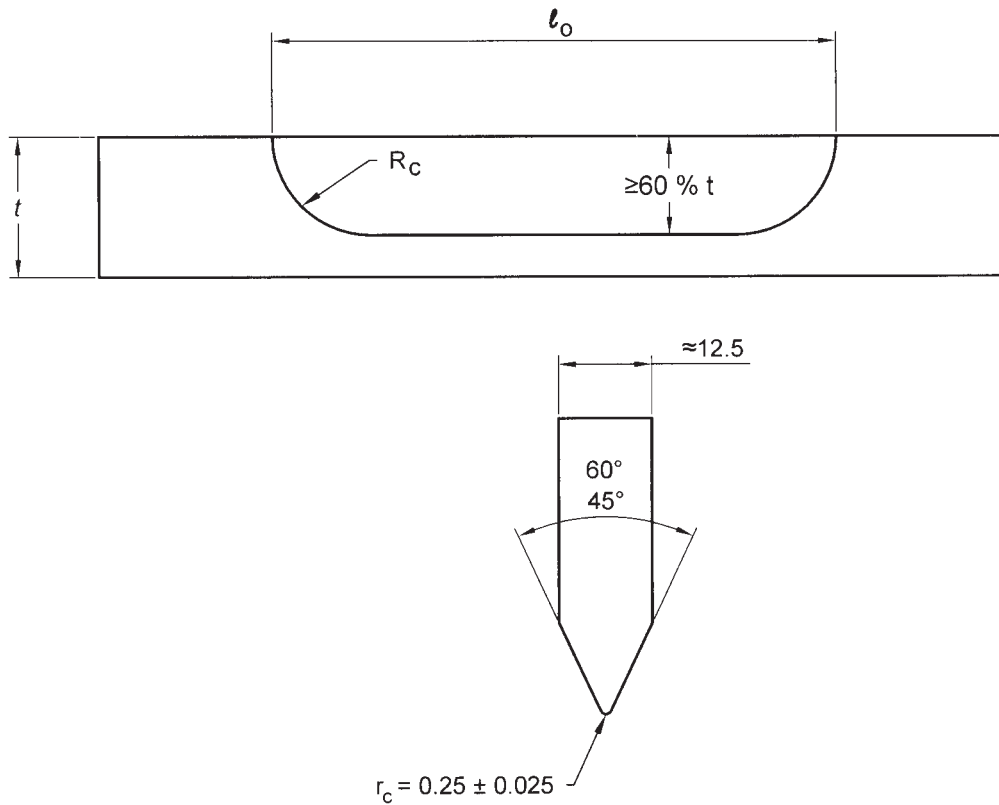
Figure 10 gives an overall view of the flaw and cutter geometries.

B-3.2 Test Procedure**B-3.2.1 General**

Subject the flawed gas cylinders to either one of the two procedures described in **B-3.2.2** and **B-3.2.3**.

B-3.2.2 Pressure-Cycling Test Procedure

Subject each flawed gas cylinder to hydraulic



All dimensions in millimetres.

FIG. 10 OVERALL VIEW OF THE FLAW AND CUTTER GEOMETRIES

pressure-cycling until failure, using the procedure described in 8.2.3, except that

- the upper cycling pressure, U_p , shall be at least $2/3 P_h \times (t/a)$, and
- the cycling frequency shall not exceed 5 cycles per min.

B-3.2.3 Constant-pressure Test Procedure

Hydraulically pressurize each flawed gas cylinder to failure using the test procedure described in 11.2.1, except for the duration of the test, which shall not be less than 1 min.

B-3.3 Acceptance Criteria

B-3.3.1 Pressure-cycling Test

- The gas cylinder is deemed to have passed the test if the failure occurs by leakage, that is the overall length of the flaw after failure, as measured on the outer surface of the gas cylinder, does not exceed $1.1 \times l_o$.
- If the criterion as per (a) of this sub-clause is not met, then the corresponding type/batch, as applicable, shall be deemed to have failed the test.

- If the number of cycles to failure falls well outside the range usually observed, typically when the crack propagation deviates from the radial direction, the test may be carried out again, but in this case two new gas cylinders shall be tested. If either of these new gas cylinders fails the test, then the corresponding type/batch, as applicable, shall be deemed to have failed the test.

B-3.3.2 Constant-pressure Test

- The gas cylinder is deemed to have passed the test when the following conditions are simultaneously fulfilled:
 - the failure shall occur by leakage, that is, the overall length of the flaw after failure, as measured on the outer surface of the gas cylinder, shall not exceed $1.1 \times l_o$; and
 - the failure pressure, P_f , shall be at least $2/3 P_h \times (t/a)$.
- If the failure pressure is less than $2/3 P_h \times (t/a)$ and failure occurs by leakage, a new test may be carried out with a less deep flaw, the acceptance criteria remaining unchanged.

- c) If the failure pressure exceeds $2/3 P_h \times (t/a)$ and failure occurs by bursting, then a new test may be carried out with a deeper flaw, the acceptance criteria remaining unchanged.
- d) If the criteria as per (a) of this sub-clause are not met, then the corresponding type/batch, as applicable, shall be deemed to have failed the test.

B-3.4 Parameters to be Monitored

B-3.4.1 Pressure-Cycling Test

Monitor the following parameters:

- a) actual flaw length;
- b) actual wall thickness;
- c) actual flaw depth;
- d) upper and lower cycling pressures;
- e) cycling rate;
- f) pressurizing medium used;
- g) temperature of the gas cylinder at the beginning and end of the test;
- h) number of cycles to failure; and
- j) Failure mode.

B-3.4.2 Constant-pressure Test

Monitor the following parameters:

- a) actual flaw length;
- b) actual wall thickness;
- c) actual flaw depth;
- d) failure pressure;
- e) pressurizing medium used; and
- f) failure mode.

B-4 FLAWED GAS CYLINDER CYCLE TEST (FCC TEST)

B-4.1 Flaw Production Procedure

The test shall be carried out on two gas cylinders. One flaw shall be machined on each gas cylinder to be tested. The flaw shall be machined longitudinally. It shall be located approximately at the mid-length of the cylindrical part of the gas cylinder, and at the point where the minimum wall thickness of this mid-section is recorded (based on four measurements equally spaced around the circumference).

The flaw length, l_o , shall be the overall length of the cut and shall be at least equal to $4a$, where a is the calculated minimum thickness of the cylindrical shell (see Fig. 1).

The cutter used to machine the flaw shall be approximately 12.5 mm thick, with an angle of 45° to 60° and a tip radius, r_c , of (0.25 ± 0.05) mm. The cutter

diameter ($= 2 \times R_c$, where R_c is the radius of curvature of the end of the flaw as shown in Fig. 10) shall be 20 mm for gas cylinders with a nominal outside diameter, D , not greater than 140 mm and 30 mm for gas cylinders with D greater than 140 mm. A standard computer numerical controlled (CNC) cutter is recommended.

The depth of the flaw shall be equal to 10 percent of the actual wall thickness, t , of the gas cylinder at the flaw location.

When measuring the actual depth of the flaw after machining, a deviation not exceeding 0.10 mm from the depth specified is acceptable

The cutter should be sharpened regularly to ensure that the tip radius meets the requirements.

B-4.2 Pressure-cycling Procedure

Subject each flawed gas cylinder to hydraulic pressure-cycling until failure, using the procedure described in 8.2.3, except that

- a) the upper cycling pressure shall be at least equal to P_h , and
- b) the cycling frequency shall not exceed 5 cycles per min.

B-4.3 Acceptance Criteria

The test is deemed to have been passed if the mean value, for the two gas cylinders tested, of the number of cycles achieved without failure exceeds 2 000, with an absolute minimum of 1 500 for each gas cylinder.

B-4.4 Parameters to be Monitored

Monitor the following parameters:

- a) actual flaw length,
- b) actual wall thickness,
- c) actual flaw depth,
- d) upper and lower cycling pressures,
- e) pressurizing medium used,
- f) temperature of the gas cylinder at the beginning and end of the test,
- g) number of cycles without failure, and
- h) description of the failure.

B-5 FREQUENCY OF TESTING

B-5.1 Prototype Testing

B-5.1.1 LBB Test

This test shall be carried out for each new design (see 8.1 for the definition of a new design). Two gases cylinders selected from the batch of gas cylinders submitted to prototype testing shall be subjected to the LBB test.

B-5.1.2 FCC Test

This test shall be carried out for each new design (*see 8.1* for the definition of a new design). Two gas cylinders selected from the batch of gas cylinders submitted to prototype testing shall be subjected to the FCC test.

B-5.2 Production Testing

In order to establish an initial database and to confirm the results obtained during prototype testing, enhanced testing is required when a manufacturer starts the production of gas cylinders using the provisions of this Annex.

Only the LBB test is required for production testing.

One gas cylinder selected from the batch of gas cylinders submitted to production testing shall be subjected to the LBB test.

For each new design (*see 8.1* for the definition of a new design), this test is required until a minimum of

10 batches of that same design have been successfully tested. In addition, this test is required until batches (of the same or of different designs) manufactured from a minimum of five different casts have been successfully tested.

The manufacturer shall keep a record of all such tests carried out, to be presented upon request.

B-6 SPECIFIC REQUIREMENTS FOR ALLOYS WITH AN ELONGATION AFTER FRACTURE BELOW 12 PERCENT

For such alloys, the manufacturer shall specify the chemistry and tolerances, the associated heat treatment and the manufacturing route. As an example, the specification for alloy 2 001 made by a hot-extrusion manufacturing route is given in Table 3. Table 3 gives the chemical composition of the aluminium alloy registered with the aluminium association.

Table 3 Chemical Composition of Aluminium Alloy 2 001

(Clause B-6)

Type of Alloy (AA Registered Designation)	Marking Code Reference	Chemical Composition (percent by mass)														
			Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Zr	Others		Al	Remarks
													Each	Total		
2 001	2 001	Min	-	-	5.2	0.15	0.20	-	-	-	-	-	-	-	Remainder	Pb: 0.003 Max
		Max	0.2	0.20	6.0	0.50	0.45	0.10	0.05	0.10	0.20	0.05	0.05	0.15		

As an example of what information is required with reference to 5.2, alloy 2 001 shall be artificially aged at a temperature of $(180 \pm 5) ^\circ\text{C}$ for a minimum of 24 h, after a suitable solution heat treatment and quench. This information shall be made available to the Inspection Body.

With reference to 7.1, the gas cylinders shall be produced from cast or extruded billet.

With reference to 9.2.2, the elongation after fracture shall not be less than 9 percent when the tensile test is carried out on a single test specimen taken from the gas cylinder wall. The tensile test may also be carried out on four test specimens distributed uniformly throughout the gas cylinder wall, in which case the results shall be as follows:

- no individual value may be less than 8 percent, and
- the average of the four measurements shall be at least 9 percent.

ANNEX C

CORROSION TESTS

[Clause 8.2.2 (a) (5)]

C-1 TESTS FOR ASSESSING SUSCEPTIBILITY TO INTER-CRYSTALLINE CORROSION

C-1.1 Principle

The method described below consists of simultaneously immersing the specimens taken from the finished gas cylinder under test in a corrosive solution and examining them after a specified etching time in order to detect any signs of inter-crystalline corrosion and to determine the nature and degree of such corrosion. The propagation of inter-crystalline corrosion is determined metallographic-ally on polished surfaces cut transversely to the etched surface.

C-1.2 Taking Specimens

Take specimens from the head, body and base of the gas cylinder (*see* Fig. 11) so that the tests with the solution as specified in C-1.4.1 can be carried out on metal from three parts of the gas cylinder.

Each specimen shall be of the dimensions and the general shape indicated in Fig. 12.

Faces $a_1a_2a_3a_4$, $b_1b_2b_3b_4$, $a_1a_2b_2b_1$ and $a_4a_3b_3b_4$ shall all be sawn with a band saw and then carefully trimmed with a fine file. The surfaces $a_1a_4b_4b_1$ and $a_2a_3b_3b_2$ which correspond respectively to the inner and outer faces of the gas cylinder shall be left in their rough state.

C-1.3 Preparation of Surface Before Corrosive Etching

C-1.3.1 Reagents

C-1.3.1.1 Nitric acid (HNO_3) analytical grade, density 1.33 g/cm³.

C-1.3.1.2 Hydrofluoric acid (HF) analytical grade, density 1.14 g/cm³ (at 40 percent).

C-1.3.1.3 De-ionized or distilled water.

C-1.3.2 Method

Prepare the following solution in a beaker:

HNO_3 (C-1.3.1.1) : 63 cm³

HF (C-1.3.1.2) : 6 cm³

H_2O (C-1.3.1.3) : 931 cm³

Bring the solution to a temperature of 95°C. Treat each specimen, suspended on a wire made of aluminium or another inert material, in this solution for 1 min. Wash in running water and then in de-

ionized or distilled water (C-1.3.1.3). Immerse the specimen in nitric acid (C-1.3.1.1) for 1 min at room temperature to remove any copper deposit which may have formed. Rinse in de-ionized or distilled water. To prevent oxidation of specimens plunge them, as soon as they have been prepared, into the corrosion bath intended for them (*see* C-1.4.1).

C-1.4 Performance of Test

C-1.4.1 Corrosive Solution

The corrosive solution to be used shall contain 57 g/l of sodium chloride and 3 g/l of hydrogen peroxide.

C-1.4.2 Preparation of the Corrosive Solution

C-1.4.2.1 Reagents

C-1.4.2.1.1 Sodium chloride ($NaCl$), crystallized, analytical grade

C-1.4.2.1.2 Hydrogen peroxide (H_2O_2), 100 to 110 volume

C-1.4.2.1.3 Potassium permanganate ($KMnO_4$), analytical grade

C-1.4.2.1.4 Sulphuric acid (H_2SO_4) analytical grade, density 1.83 g/cm³

C-1.4.2.1.5 De-ionized or Distilled water

C-1.4.2.2 Titration of Hydrogen Peroxide

Since hydrogen peroxide is not very stable, it is essential to check its titre before use. To do this, take 10 cm³ of hydrogen peroxide (C-1.4.2.1.2) with a pipette and dilute to 1 000 cm³ (in a volumetric flask) with de-ionized or distilled water (C-1.4.2.1.5) thus obtaining a hydrogen peroxide solution which will be called solution C. Using a pipette, place in a conical flask:

- a) Ten cm³ of the hydrogen peroxide solution C, and
- b) Approximately 2 cm³ of sulphuric acid (C-1.4.2.1.4).

Use a solution of potassium permanganate at 1.859 g/l (C-1.4.2.1.3) for the titration. The potassium permanganate itself acts as an indicator.

C-1.4.2.3 Explanation of titration

The reaction of the potassium permanganate with hydrogen peroxide in a sulphuric medium is described by the following equation:

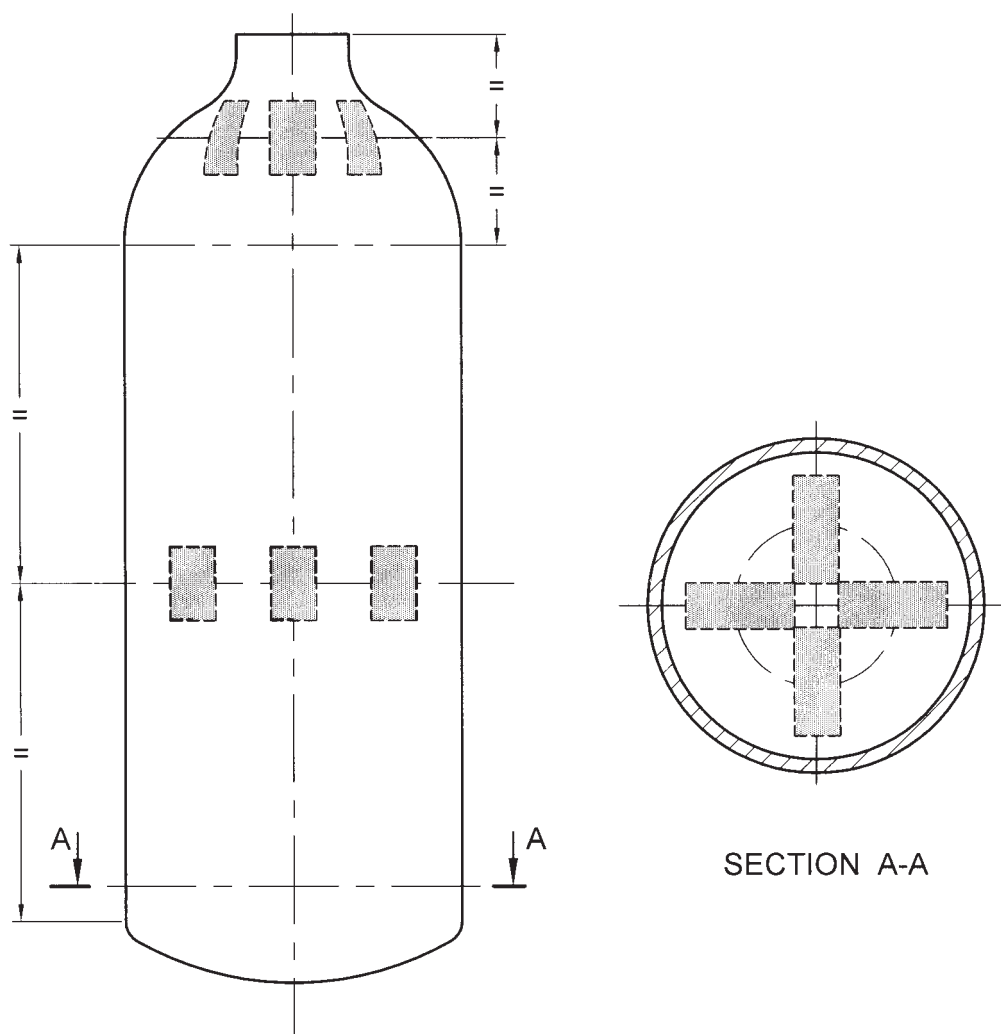
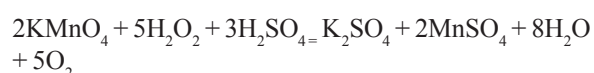


FIG. 11 LOCATION OF SPECIMENS



which gives the equivalence: $316 \text{ g KMnO}_4 = 170 \text{ g H}_2\text{O}_2$.

Therefore 1 g of pure hydrogen peroxide reacts with 1.859 g of potassium permanganate, hence the use of a 1.859 g/l solution of potassium permanganate, which neutralizes, volume for volume, one gram per litre solution of hydrogen peroxide- Since the hydrogen peroxide was diluted $100 \times$ to begin with, the 10 cm^3 of solution C taken represents 0.1 cm^3 of the original hydrogen peroxide.

By multiplying by 10 the number of cubic centimetres of potassium permanganate solution used for the titration, the titre T , of the original hydrogen peroxide, in g/l, is obtained.

C-1.4.2.4 Preparation of the solution

Method for 10 litre:

Dissolve 570 g of sodium chloride (C-1.4.2.1.1) in

de-ionized or distilled water (C-1.4.2.1.5) to obtain a total volume of about nine litres. Add the quantity of hydrogen peroxide (C-1.4.2.1.2) calculated below. Mix and then make up the volume to ten litres with de-ionized or distilled water.

Calculate the volume of hydrogen peroxide to be put into the solution as follows:

Quantity of pure hydrogen peroxide required: 30 g

If the hydrogen peroxide contains T grams of H_2O_2 per litre, the volume required, expressed in cubic centimetres, will be:

$$\frac{1\,000 \times 30}{T}$$

C-1.4.3 Etching Procedure

C-1.4.3.1 Place the corrosive solution in a crystallizing dish (or possibly a large beaker), itself placed in a water bath. Keep the water bath stirred with a magnetic stirrer and regulate the temperature with a contact thermometer.

Either suspended the specimen in the corrosive solution by a wire made of aluminium (or other inert material) or placed it in the solution so that it rests only on its corners, the second method being the preferred one etch the specimen for 6 h with the temperature held at $(30 \pm 1)^\circ\text{C}$. Take care to ensure that the volume of solution used is at least 10 cm^3 per cm^2 of specimen surface.

After etching, wash the specimen in water, immerse it for about 30s in 50 percent dilute nitric acid, wash it again in water and dry it with compressed air.

C-1.4.3.2 A number of specimens may be etched at the same time provided that they are of the same type of alloy and that they are not in contact. The minimum volume of reagent per unit of specimen surface area shall be adhered to.

C-1.5 Preparation of Specimens for Examination

C-1.5.1 Apparatus and Materials Required

C-1.5.1.1 Casting Dishes, with, for example, the following dimensions:

External diameter: 40 mm; Height: 27 mm; Wall thickness: 2.5 mm.

C-1.5.1.2 Epoxy casting resin plus hardener, or equivalent system.

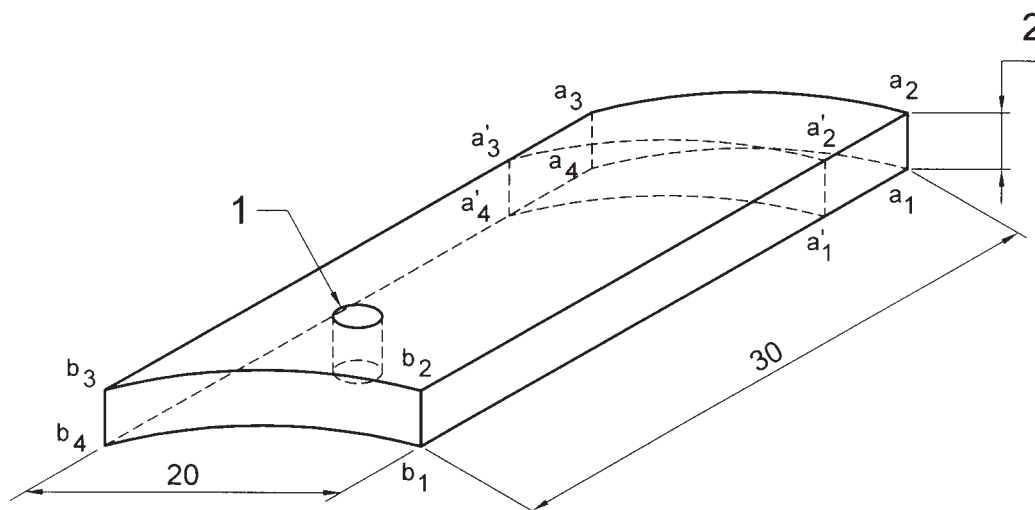
C.1.5.2 Method

Place each specimen vertically in a casting dish (**C-1.5.1.1**) so that it rests on face $a_1a_2a_3a_4$. Pour around it a mixture of the epoxy resin and hardener (or equivalent) (**C-1.5.1.2**) in the appropriate proportions.

Remove a certain amount of material from the face $a_1a_2a_3a_4$, preferably with a lathe, so that the section $a'_1a'_2a'_3a'_4$, when examined under the microscope, cannot show corrosion from face $a_1a_2a_3a_4$. The distance between faces $a_1a_2a_3a_4$ and $a'_1a'_2a'_3a'_4$, that is, the thickness removed by the lathe, shall be at least 2 mm (see Fig. 12 and Fig. 13).

Alternatively, prepare a section by sawing through plane $a'_1a'_2a'_3a'_4$ (see Fig. 12) to remove a specimen between 5 mm and 10 mm thick (that is, such that the distance from a'_1 to a_1 is between 5 mm and 10 mm). Mount this specimen in thermosetting or thermoplastic mounting compound with face $a'_1a'_2a'_3a'_4$ exposed to allow mechanical polishing.

Polish the section for examination mechanically with abrasive paper, a diamond compound and/or magnesia polishing compound.



Key

- 1 — Hole $\phi 3$
- 2 — Thickness of the cylinder wall

All dimensions in millimetres.

FIG. 12 SPECIMEN SHAPE AND DIMENSIONS

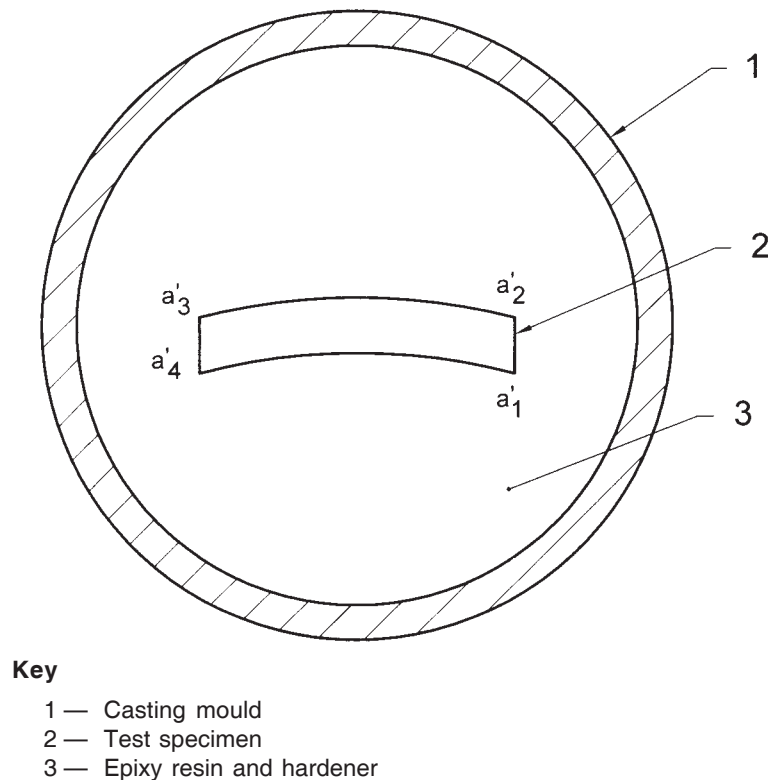


FIG. 13 SPECIMEN IN CASTING DISH

C-1.6 Micrographic Examination of Specimens

The examination is intended to assess the degree of penetration of the inter-crystallization corrosion into each of the two faces which make up the outer and inner surfaces of the gas cylinder.

First examine the section at low magnification (for example, 40X) in order to locate the most corroded areas, and then at a higher magnification, usually about 300X, in order to assess the nature and extent of the corrosion.

C-1.7 Interpretation of Micrographic Examination

- a) For alloys with an equi-axed crystal structure the depth of corrosion shall not exceed the greater of the following two values:
 - 1) three grains in the direction perpendicular to the face examined.
 - 2) 0.2 mm.

But in no case shall the depth exceed 0.3 mm. However, it is permissible for these values to be exceeded locally provided that they are not exceeded in more than four fields of examination at 300X magnification.

- b) For alloys with a crystal structure oriented in one direction through cold working, the

depth of corrosion into each of the two faces which make up the internal and external surfaces of the gas cylinder shall not exceed 0.1 mm.

C-2 TESTS FOR ASSESSING SUSCEPTIBILITY TO STRESS CORROSION

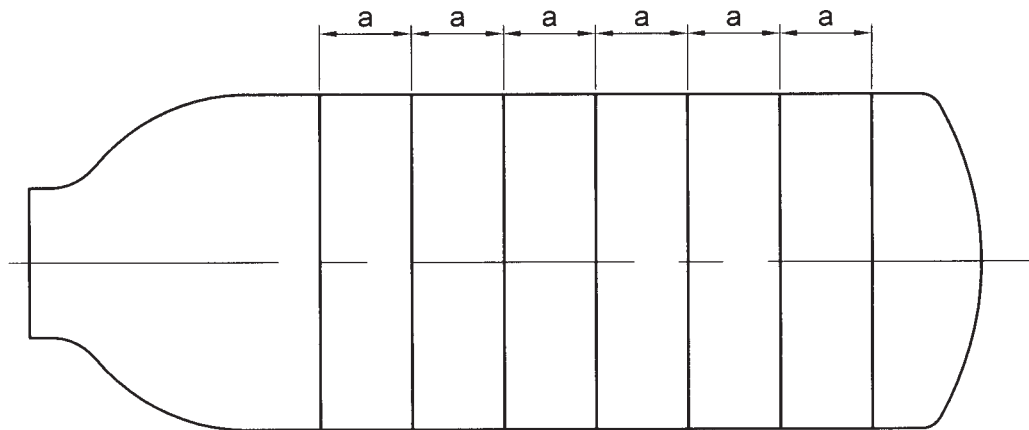
C-2.1 Principle

The method described below involves subjecting rings cut from the cylindrical part of the gas cylinder to stress and immersing them in brine for a specific period, followed by removal of the brine and exposure of the rings to the air for a longer period, this cycle being repeated for 30 days. If there are no cracks after the period of 30 days, the alloy is considered suitable for the manufacture of gas cylinders.

C-2.2 Tests Specimens

Cut six rings with a width of 4× the actual thickness or 25 mm, whichever is the greater, from the cylindrical part of the gas cylinder (*see* Fig. 14). Make a 60° cut-out in each specimen and subject them to stress by means of a threaded bolt and two nuts (*see* Fig. 15).

Neither inner nor outer surfaces of the specimens shall be machined.



$a = 4 \times$ The actual wall thickness in millimetres, or 25 millimetres, whichever is the greater

FIG. 14 SPECIMEN RING LOCATIONS

C-2.3 Surface Preparation before Corrosion Test

Remove all traces of grease, oil and adhesive used with stress gauges (*see* C-2.4.2) with a suitable solvent.

C-2.4 Performance of the Test

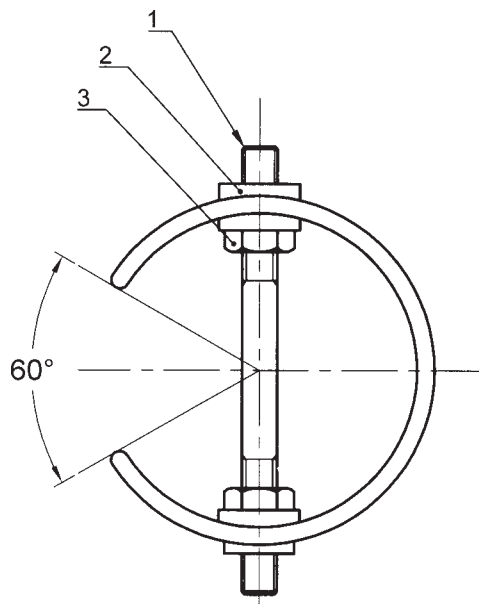
C-2.4.1 Preparation of Corrosive Solution

Prepare the brine by dissolving (3.5 ± 0.1) parts by mass of sodium chloride in 96.5 parts by mass of water. The pH of the freshly prepared solution shall

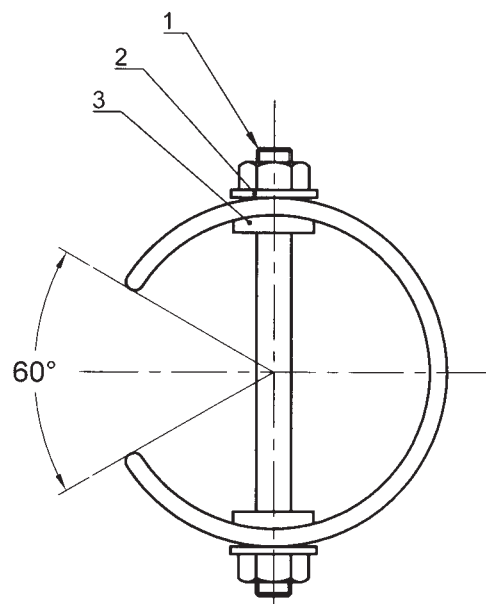
be in the range 6.4 to 7.2. The pH may be corrected only by using dilute hydrochloric acid or dilute sodium hydroxide.

The solution shall not be topped up by adding the salt solution prepared in C-1.4.2.4, but only by adding distilled water up to the initial level in the vessel. Topping up may be carried out daily if required.

The solution shall be completely replaced every week.



15 A Stressed internally



15 B Stressed externally

Key

- 1 — Threaded bar
- 2 — Insulating bush
- 3 — Nut

FIG. 15 STRESSED SPECIMENS

C-2.4.2 Applying the Stress to the Rings

Three of the rings shall be compressed so that the outer surface is under tension. The other three rings shall be expanded so that the inner surface is under tension.

The rings shall be stressed to a maximum value given by:

$$\text{Maximum stress} = R_e \times F$$

where

R_e = guaranteed minimum 0.2 percent proof strength in MPa, and

F = design stress factor (variable).

The actual stress may be measured by electric stress gauges.

The diameter of the ring corresponding to the required maximum stress can be calculated using the following equation:

$$D' = D \pm \frac{\pi R(D-t)^2}{4EtZ}$$

where

D' = outside diameter of the ring when compressed (or when expanded), in millimetres;

D = outside diameter of the gas cylinder, in millimetres;

t = gas cylinder wall thickness, in millimetres;

R = maximum stress value, $R_e \times F$ in MPa;

E = modulus of elasticity, in MPa (70 000 MPa approximately); and

Z = correction factor (see Fig. 16).

It is essential for the nuts and bolts be electrically insulated from the rings and protected from corrosion caused by the salt solution. Immerse the six rings completely in the salt solution for 10 min. Then remove them from the solution and expose them to the air for 50 min. Repeat this cycle for 30 days or until a ring breaks, whichever happens first. Inspect the specimens visually for any cracks.

C-2.5 Interpretation of Results

The alloy shall be considered acceptable for the manufacture of gas cylinders if none of the rings subjected to stress has developed any cracks visible to the naked eye, or visible at low magnification (10X to 30X), at the end of the 30-day test period.

C-2.6 Possible Metallographic Examination

C-2.6.1 In the event of doubt about the presence of cracks (for example, if a line of pitting is present), the uncertainty may be removed by means of an

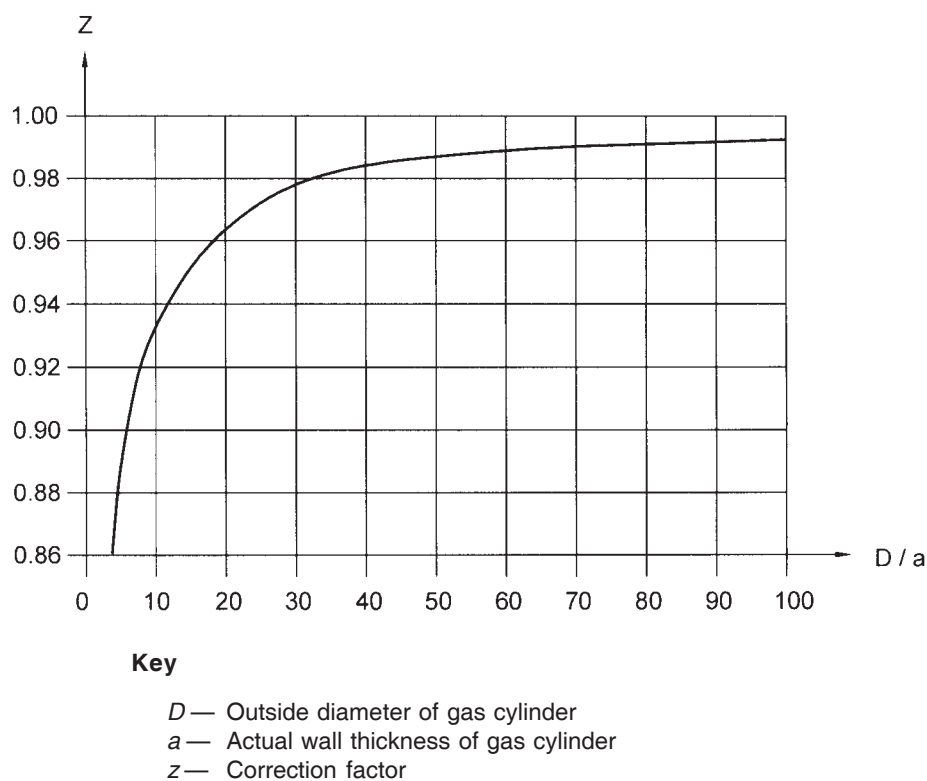


FIG. 16 CORRECTION FACTOR, Z

additional metallographic examination of a section taken perpendicular to the axis of the ring in the suspect area. A comparison is made of the form (inter-crystalline or trans-crystalline) and depth of penetration of the corrosion on the faces of the ring subject to tensile and compressive stress.

C-2.6.2 The alloy shall be considered acceptable if the corrosion on both faces of the ring is similar.

If, however, the face of the ring under tension reveals inter-crystalline cracks which are clearly deeper than those in the face under compression, the ring shall be considered to have failed the test.

C-2.7 Test Report

The test report shall state at least the following details:

- a) The name of the alloy and/or its standard number;
- b) The composition limits of the alloy;
- c) The actual analysis of the cast from which the gas cylinders were manufactured;
- d) The actual mechanical properties of the alloy, together with the minimum mechanical-property requirements; and
- e) The result of the test.

ANNEX D

[Clause 8.2.2 (a) (6)]

TEST METHOD TO DETERMINED SUSTAINED-LOAD-CRACKING RESISTANCE OF ALUMINIUM ALLOY GAS CYLINDERS

D-1 PRINCIPLE

A fatigue pre-cracked specimen is loaded by a constant-load or constant-displacement method to a stress-intensity factor, K_{IAPP} equal to a defined value. The specimen is kept in the loaded condition for a specified time and at a specified temperature. After this test period, the specimen is examined to assess whether the initial fatigue crack did or did not grow.

If the test specimen exhibits less than or equal to a specified amount of crack growth, then the material is considered suitable for gas cylinders with respect to the sustained-load-cracking resistance requirement.

D-2 GENERAL

This method covers the determination of the sustained-load-cracking resistance for aluminium alloy gas cylinders.

Following the initial qualification for resistance to sustained-load-cracking, this procedure shall only be repeated if any of the conditions (a), (b), (c) or (d) as listed in **8.1** apply.

Testing shall be conducted using the applicable requirements of ISO 7539-6 and the additional requirements specified in this standard. Requirements given in ISO 7539-6 for corrosive environments need not be satisfied.

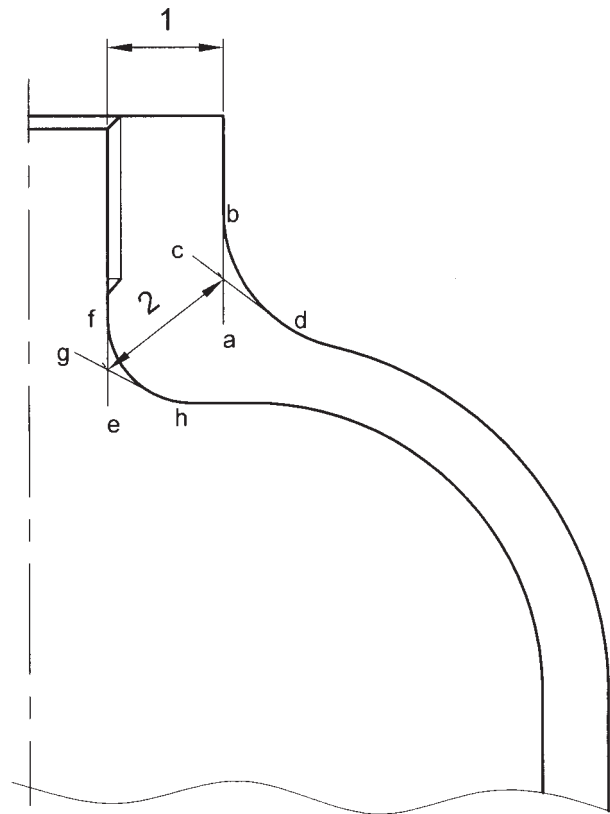
Gas cylinders with nominal neck and shoulder wall

thicknesses ≤ 7 mm are exempt from the sustained-load-cracking tests. The inspection body shall ensure that the neck and shoulder wall thickness of the actual gas cylinders reasonably represents the quoted nominal Figure. Figure 17 illustrates the neck and shoulder thicknesses.

D-3 TERMS, DEFINITIONS AND SYMBOLS

For the purposes of this Annex, the terms, definitions and symbols given in ISO 7539-6 and the following apply.

SLC	—	sustained-load cracking
K_{IAPP}	—	applied elastic-stress intensity factor, in MPa.
E	—	modulus of elasticity, in MPa
R_{eSLC}	—	average of the measured yield strength, in MPa, of two specimens, from the test gas cylinder, representing the SLC test specimen locations at room temperature (for locations of specimens, <i>see</i> D-4.3)
V	—	crack-mouth opening displacement (CMOD), in millimetres, defined as the mode 1 (also called opening-mode) component of crack displacement due to elastic and plastic deformation, measured at the location on a crack surface that has the greatest elastic displacement per unit load



Key

- 1 — Nominal neck thickness
2 — Nominal shoulder thickness

NOTE — *ab, cd, ef* and *gh* are tangents initiating at intersecting surfaces.

FIG. 17 ILLUSTRATION OF NECK AND SHOULDER THICKNESS

D-4 SPECIMEN CONFIGURATIONS AND NUMBERS OF TESTS

D-4.1 One of the following specimen geometries, or a combination of them, shall be used for the tests:

- Compact tension-test (CTT) specimen, as shown in Fig. 3 in ISO 7539-6;
- Double cantilever beam (DCB) specimen, as shown in Fig. 4 in ISO 7539-6;
- Modified wedge opening loaded (modified WOL) specimen, as shown in Fig. 5 in ISO 7539-6; and
- C-shaped specimen as shown in Fig. 6 in ISO 7539-6.

D-4.2 Specimen orientation shall be Y-X or Y-Z as shown in Fig. 18.

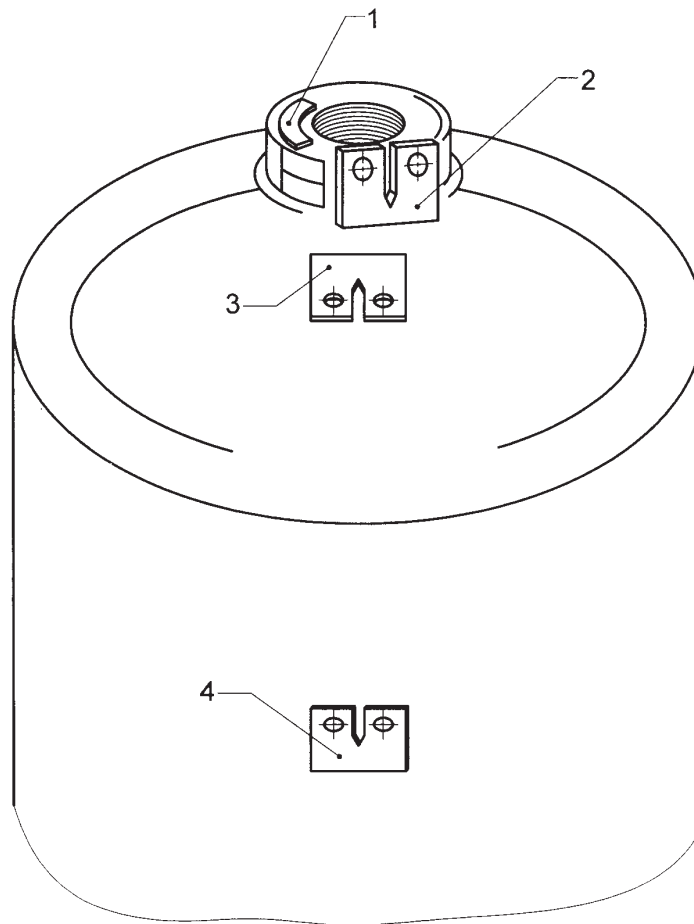
D-4.3 At least three specimens from the gas cylinder wall and, if possible three specimens from the shoulder and three specimens from the neck shall be

tested. At each location the three specimens shall be taken as close to each other as possible — One specimen from each location shall be used for SLC testing and two from each location for tensile testing (*see* Fig. 18).

D-4.4 Flattening of test specimens is not allowed.

D-4.5 If test specimens with the thickness necessary to meet the **D-6.7** validity requirements cannot be obtained from the specified location or locations, then the thickest possible specimens shall be tested. The specimens shall be taken when the mechanical properties of the gas cylinder have been fully developed, but before any external machining of the neck/shoulder area.

D-4.6 When it is impossible to obtain full-size tensile specimens, small-size specimens in accordance with IS 1608 are permitted for the determination of the yield strength.

**Key**

- | | |
|-------------------------|--|
| 1 — Y - Z Neck specimen | 3 — Y - X Shoulder specimen, taken as close as possible to the neck with notch tip toward the neck, as shown |
| 2 — Y - X Neck specimen | 4 — X Cylinder wall specimen |

FIG. 18 ORIENTATION OF NECK, SHOULDER AND GAS CYLINDER WALL SPECIMENS

D-5 FATIGUE PRE-CRACKING

All requirements specified in 6 of ISO 7539-6 shall be satisfied, except that the fatigue crack length (a , in mm) requirement in 6.4 of ISO 7539-6 shall be given by the following equation:

$$a \geq 1.27 (K_{IAPP}/R_{eSLC})^2 \times 1\,000$$

D-6 SPECIMEN TESTING PROCEDURE

D-6.1 All requirements specified in 7 of ISO 7539-6 shall be satisfied, except that the requirements of 7.2.2, 7.2.6, 7.5.1, 7.5.2, 7.5.4, 7.5.5 need not be satisfied.

D-6.2 Load the fatigue-pre-cracked specimens to a stress intensity factor, K_{IAPP} , determined from the following equation:

$$K_{IAPP} = 0.056 R_{eSLC}$$

Specimens shall be loaded by a suitable constant-displacement or constant-load method.

D-6.3 For specimens loaded by a constant-displacement method, the loading shall be determined by either the non-monitored-load method or the monitored-load method and shall meet the following requirements.

- a) For the non-monitored-load method:
 - 1) At the end of the test, record the crack mouth opening displacement (CMOD) before unloading.
 - 2) Unload the specimen.
 - 3) Reload the specimen up to the measured

CMOD in a device suitable for load measurement. Record the load and use this load in the K_{IAPP} calculations. This calculated K_{IAPP} shall be equal to or greater than the K_{IAPP} value calculated from **D-6.2**.

b) For the monitored-load method:

- 1) Use the final load at the end of the test period in the calculation of K_{IAPP} .
- 2) This calculated value of K_{IAPP} shall be equal to or greater than the K_{IAPP} value calculated from **D-6.2**.

D-6.4 For the constant-displacement method, the crack mouth opening displacement, V , shall be determined as follows:

- a) For testing of CTS specimens at a constant-displacement loading, use the following equations to determine V :

$$V = \frac{K_{IAPP} \times \sqrt{W}}{0.032 \times E \times f(x) \times \sqrt{\frac{B}{B_N}}}$$

$$f(x) = \frac{2.24 \times (1.72 - 0.9x + x^2) \times \sqrt{1-x}}{9.85 - 0.17x + 11.4x^2}$$

$$x = \frac{a}{W}$$

- b) For testing of C-shaped specimens at a constant-displacement loading, use the following equations:

For specimens with $X/W = 0$

$$V = \frac{K_{IAPP} \times \sqrt{W} \times P_1 \times [0.43(1 - r_1/r_2) + Q_1]}{0.032 \times E \times Y}$$

For specimens with $X/W = 0.5$:

$$V = \frac{K_{IAPP} \times \sqrt{W} \times P_2 \times [0.45(1 - r_1/r_2) + Q_2]}{0.032 \times E \times Y}$$

where

W — effective width of the specimen measured from the back face to either the face containing the notch, or the loading plane, depending on the specimen geometry;

B — side-to-side dimension of the specimen being tested;

B_N — minimum side-to-side dimension between the notches in side-grooved specimens; and

Y — as defined in ISO 7539-6, Fig. 14;

$$P_1 = (1 + a/W) / (1 - 6 a/W)^2;$$

$$Q_1 = 0.542 + 13.137 (a/W) - 612.316 (a/W)^2 + 6.576 (a/W)^3;$$

$$P_2 = (2 + a/W) / (1 - 6 a/W)^2;$$

$$Q_2 = 0.399 + 12.63 (a/W) - 9.838 (a/W)^2 + 4.66 (a/W)^3.$$

- c) The stress-intensity factor equations provided in ISO 7539-6 shall be used in testing of DCB and modified -WOL specimens in the constant — displacement mode.

D-6.5 For Constant-Loading Method

- a) for testing of DCB specimens at a constant load, use the following equation (see Reference [7] for further information):

$$K_{IAPP} = P_a / (BH^{3/2}) (3.46 + 2.38/a)$$

where

B — side-to-side dimension of the specimen being tested;

P_a — applied load.

The above equation shall satisfy the following validity requirements.

$$2 \leq a/H \leq 10$$

$$W \geq a + 2H$$

- b) for testing of CTS, modified-WOL and C-shaped specimens at a constant load, the stress-intensity factor equations provided in ISO 7539-6 shall be used.

D-6.6 The loaded specimens shall be tested for 90 days at $(23 \pm 5)^\circ\text{C}$ or for 30 days at $(80 \pm 5)^\circ\text{C}$.

D-6.7 The validity condition given in 7.6.6, item e) of ISO 7539-6 shall be replaced by the following condition. All specimens shall meet the validity requirements except as exempted in **D-4.5**.

$$a, B, B_N (W - a) \geq 1.27 (K_{IAPP} / R_{eSLC})^2 \times 1\,000$$

D-6.8 If the additional test referred to in **D-7.4** is required, then repeat the entire procedure using only constant-load conditions as described in **D-6.5** for a period of 180 days at room temperature

D-7 CRACK GROWTH EXAMINATION

D-7.1 After the specified test period, unload the specimen and fatigue the specimen at a maximum stress intensity not exceeding $0.6 K_{IAPP}$ until the crack advances by at least one millimeter. After this fatigue cracking, break open the specimen.

D-7.2 Measure the distance between the pre- and post-fatigue crack using a scanning electron microscope (SEM) take the measurements perpendicular to the pre-fatigue and post-fatigue cracks at locations representing

25 percent of B, 50 percent of B and 75 percent of B. Calculate the average of these three values.

D-7.3 If the average measured distance between the two fatigue cracks does not exceed 0.16 mm, the specimen passes the test. If all specimens pass, the alloy/process is considered to be qualified (*see D-8*).

D-7.4 If the average measured values from **D-7.3** exceed 0.16 mm, the alloy/process may be qualified if, when subjected to the additional test described in **D-6.8**, the average measured distance between the two fatigue cracks shall not exceed 0.3 mm. **D-7.1** and **D-7.2** shall also apply.

D-8 GAS CYLINDER THICKNESS QUALIFICATION

If the validity requirements of **D-6.7** are not met, then

the material is suitable up to the maximum thickness of the gas cylinder location from where the specimens were taken, provided the specimens meet the other requirements of this test. The material is suitable for all thicknesses if the specimens meet the validity requirements of **D-6.7** as well as the other requirements of this test method.

D-9 TEST REPORT

The information required in ISO 7539-6, clause **8**, with the exception of **8.5**, shall be reported. The report shall indicate if the validity criteria are met or not and shall include an SEM micrograph as per **D-7.2**. The test report shall be kept on file permanently as a record that the gas cylinder alloy/process has been tested and found acceptable.

ANNEX E

(Clause 8.3)

EXAMPLE OF TYPE APPROVAL AND PRODUCTION TESTING CERTIFICATES

E-1 TYPE APPROVAL CERTIFICATE

Issued by(Relevant authority).....on the basis of
applying
 IS:.....concerning seamless aluminium alloy gas cylinder
 Approval No. Date.....
 Type of cylinder.....(Description of the family of cylinders which has received type approval)

 P_h D_{min} D_{max} a.....b..... L_{min}
 L_{max} V_{min} V_{max} Manufacturer or
 agent.....(name and address of manufacturer or its
 agent).....

 Type approval mark

Details of results of the examination of the type for type approval and the main features of the type are attached (see table 4 and table 5 of Annex G).

All information may be obtained from (name and address of the approving body)

Date.....Place.....

Signature.....

E-2 COMMENTS FOR USE WITH TYPE APPROVAL CERTIFICATE

- | | |
|---|--|
| <p>a) Result of type approval examination of the type with type approval details should be attached.</p> <p>b) Main features of the type should be shown, in particular:</p> <ol style="list-style-type: none"> 1) Longitudinal cross-section drawing of the type of cylinder which has received type approval showing : <ol style="list-style-type: none"> i) Minimum and maximum nominal external diameter , D_{min} and D_{max} with an indication of the design tolerances laid down by the manufacturer ii) Guaranteed minimum thickness of the cylinder wall (a); iii) Guaranteed minimum thickness of | <p>the base (b) and of the head with an indication of the design tolerances laid down by the manufacturer;</p> <ol style="list-style-type: none"> 2) Minimum and maximum length (s), L_{min}, L_{max} (L being distance from the outside of the base of the shell to the top surfaces of the cylinder neck); 3) Water capacity or capacities , V_{min}, V_{max}; 4) Hydraulic test pressure P_h; 5) Name of the manufacture / Number of the drawing and date; 6) Name of the type of cylinder ; and 7) Alloy in accordance with 5 [nature/chemical composition/method of manufacture/heat treatment/guaranteed mechanical characteristics (tensile strength, yield stress)]. |
|---|--|

ANNEX F
[Clauses 10.1 (v) and 10.7.2]

**DESCRIPTION AND EVALUATION OF MANUFACTURING SURFACE IMPERFECTIONS
AND CONDITIONS FOR REJECTION OF SEAMLESS ALUMINIUM ALLOY GAS CYLINDERS AT
TIME OF PRODUCT ACCEPTANCE**

F-1 INTRODUCTION

Several types of imperfection can occur during the manufacture of a seamless aluminium alloy gas cylinder. Most of these are cosmetic features which do not affect the performance or life of the gas cylinder. In addition to meeting the requirements of this standard, the gas cylinder should be able to pass the periodic visual inspection and testing specified in IS 16017.

The aim of this Annex is to identify the manufacturing imperfections most commonly encountered and to suggest rejection criteria for use by the purchaser(s) and their representative(s) who might perform the visual inspection and acceptance testing of the gas cylinder. Only those imperfections which were specifically contracted (by purchase order or contract) should be evaluated for acceptance or rejection.

F-2 GENERAL

F-2.1 The inspection should be conducted in appropriate lighting on a product that is both clean and dry. If unclean, the surface may be cleaned under closely controlled conditions by a suitable method before inspection. The visual inspection should be conducted by eye, without magnification. Internal inspections may be augmented by a scope, dental mirror or another suitable device.

F-2.2 Small imperfections may be removed by local dressing, grinding, machining or another appropriate method when the purchaser has stipulated, when providing the purchase contract, that such imperfections are unacceptable great care should be taken to avoid introducing new, more serious, defects. After such a repair, gas cylinders should be re-examined and, if necessary, the wall thickness rechecked.

F-3 MANUFACTURING DEFECTS AND IMPERFECTIONS

The most commonly found manufacturing defects and imperfections are listed, together with their definitions, in Table 4. The table is written with requirements to allow the table to be utilized by the purchaser for contractual purposes. Proposed acceptance/rejection limits for repair or scrap are included in the table should the purchaser wish to contract such limits. If the table is used, then the suggested acceptance/rejection criteria in the 'conditions and/or actions' column and the 'repair or scrap column' apply. These rejection limits are subjective to the purchaser and the purchaser's planned market and/or use of the product. They apply to all sizes and types of gas cylinders and service conditions. Nevertheless some purchaser specifications for some types of gas cylinders or some special service conditions may require more or less stringent criteria

Table 4 Manufacturing Defects and Imperfections*(Clause F-3)*

Defect or Imperfection	Description	Criteria for Acceptance or Rejection	Repair or Scrap
Bulge	Visible swelling of the wall.	All cylinders with such a defect	Scrap
Dent (flat)	A visible depression in the wall that has neither penetrated the wall nor removed any metal and is greater in depth than 1 percent of the outside diameter (<i>see</i> Fig. 19). (<i>see also</i> excessive grinding or Machining)	a) When the depth of the dent exceeds 2 percent of the external diameter of the cylinder or b) when the diameter of the dent is less than 30X its depth or c) when an external dent is visible on the internal surface NOTE — On small-diameter cylinders these general limits may have to be adjusted. Consideration of appearance also plays a part in the evaluation of dents, especially in the case of small cylinders.	Scrap
Cut, gouge, metallic impression	An impression in the wall where metal has been removed or redistributed (due basically to the presence of foreign bodies on the mandrel or matrix during extrusion or drawing operations) to a depth of greater than 2 percent of the diameter.	Inside imperfection a) If more than 5 percent of the wall thickness b) or if remaining wall thickness under the defect is less than $a/2$ c) or if with sharp notches d) or when the length exceeds $5 \times$ the minimum wall thickness NOTE — Consideration of appearance and location (in thicker parts with lower stresses) can be taken into account.	Scrap
		Outside imperfection When the depth exceeds 5 percent of the wall thickness or when the remaining wall thickness under the defect is less than a. When the depth is less than 5 percent of the wall thickness or when the remaining wall thickness under the defect is greater than a.	Scrap Repair if possible (<i>see</i> F.2.2)
Dent containing cut or gouge	A depression in the wall which contains a cut or gouge (<i>see</i> Fig. 20).	All cylinders with such an defect	Scrap
Excessive grinding or machining	Local reduction of wall thickness by grinding or machining.	When the wall thickness is reduced to below the minimum design thickness	Scrap
		When it results in the formation of a dent	<i>see</i> “dent” above Scrap.

Table 4 — (Continued)

Defect or Imperfection	Description	Criteria for Acceptance or Rejection	Repair or Scrap
Ridge or riba	A longitudinal raised surface with sharp corners (see Fig. 21).	Inside imperfection If the height exceeds 5 percent of the wall thickness	Scrap.
		Outside imperfection Where the height exceeds 5 percent of the wall thickness	Repair if possible (see F-2.2).
Groove	A deep longitudinal notch (see Fig. 22).	Inside imperfection If the depth exceeds 5 percent of the wall thickness or if the remaining wall thickness under the defect is less than $\dot{a}$	Scrap
		Outside imperfection If the depth exceeds 5 percent of the wall thickness or if the remaining wall thickness under the defect is less than $\dot{a}$	Scrap
		Outside imperfection If the depth is less than 5 percent of the wall thickness or if the remaining wall thickness under the defect is greater than $\dot{a}$.	Repair if possible (see F-2.2).
Lamination	Layering of the material within the cylinder wall and sometimes appearing as a discontinuity, crack, lap or bulge at the surface (see Fig. 23).	Inside imperfection All cylinders with such an imperfection	Scrap
		Outside imperfection All cylinders with such an imperfection:	Outside imperfection All cylinders with such an imperfection:
Blister	Small bulge on the wall containing a continuous layer of inclusions	Inside imperfection All cylinders with such an imperfection where blister is greater than 2 mm in diameter	Scrap
		Outside imperfection All cylinders with such an imperfection where blister is deeper than 5 percent of wall thickness	Repair if possible (see F-2.2). Not necessary to repair if clearly insignificant to cylinder Performance
Crack	A split or separation in the metal, forming a line	All cylinders with such an imperfection	Scrap
Neck cracks	Appear as lines which run vertically down the thread and across the thread faces (they should not be confused with tap marks or thread machining marks) (see Fig. 24).	All cylinders with such an imperfection	Scrap

Table 4 — (Continued)

Defect or Imperfection	Description	Criteria for Acceptance or Rejection	Repair or Scrap
Shoulder folds	Folding with peaks and troughs, situated in the internal shoulder area, which propagates into the threaded area of the shoulder (<i>see</i> Fig. 25).	When folds are visible as a line running into the threaded portion and across more than two full threads (Folds which extend beyond the machined area and are clearly visible as open depressions where no oxides have been trapped in the metal are acceptable, provided the peaks are smooth and the root of the depression is rounded.) <i>see</i> 10.5 for other criteria for scrapping and repair.	Repair or scrap. If the folding has been removed by machining and the wall thickness is satisfactory, then the imperfection is acceptable. After repairing by machining, the whole area shall be re-inspected carefully and the wall thickness verified.
Shoulder cracks	Can start in the internal shoulder area and propagate into the cylindrical machined or threaded area of the shoulder (Fig. 26 shows where shoulder cracks start and how they propagate).	If cracks are visible along their whole length or if wall thickness is unsatisfactory	Scrap
Internal threads damaged or out of tolerance	Threads damaged, with dents, cuts or burrs, or out of tolerance	If the design permits	Repair by re-tapping and rechecking the threads with the appropriate thread gauge followed by careful visual reexamination. Re-tapped threads must meet at least the minimum design requirements
		If not repairable	Scrap
Pitting	Small holes in metal due to chemical or water attack	Inside imperfection If the diameter of the largest pit is greater than 2 mm or if the depth of any pit is greater than 2 percent of the wall thickness	Scrap
		Outside imperfection All cylinders with such defects of depth less than 2 percent of the wall thickness.	Repair if possible (<i>see</i> F-2.2).
Non-conformity with design drawing	Does not conform to the design drawing (concerning <i>for example</i> neck or bottom shape and dimensions, out of straightness, stability, lack of thickness)	All cylinders presenting such an imperfection	Repair if possible (<i>see</i> F-2.2) or, if this is unacceptable to the purchaser, scrap

Table 4 — (Concluded)

Defect or Imperfection	Description	Criteria for Acceptance or Rejection	Repair or Scrap
Neck ring not secure	Neck ring turns under application of low torque or pulls off under low axial load (<i>see 6.6</i>)	All cylinders presenting such an imperfection	Repair if possible (<i>see F-2.2</i>) or scrap
Arc or torch burns	Partial burning of the cylinder metal, the addition of weld metal or the removal of metal by scarfing or cratering	All cylinders presenting such an imperfection	Scrap

NOTE — Lubrication marks which arise during the extrusion process, and which can be inside or outside, are subject to a standard. Agreed between manufacturer and purchaser or purchaser's designated Inspection Body. Such marks outside the agreed limits can cause the gas cylinder to be scrapped.

At This inside imperfection, when detected before necking, may be repaired, if possible, prior to closure.

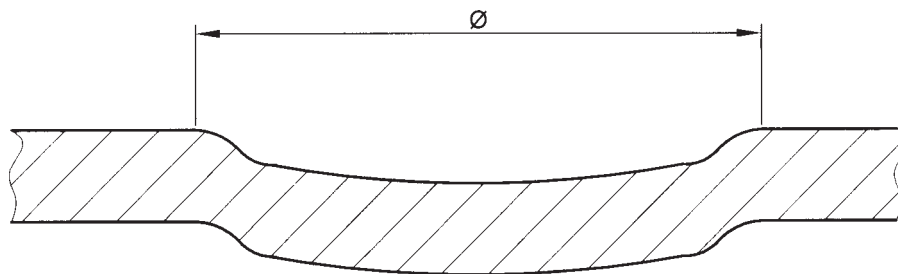


FIG. 19 DENT

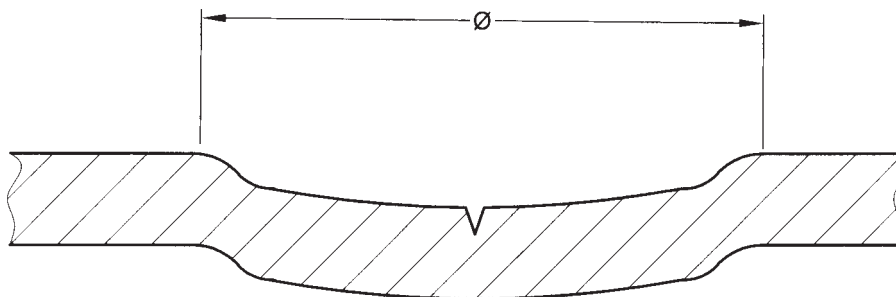


FIG. 20 DENT CONTAINING CUT OR GOUGE

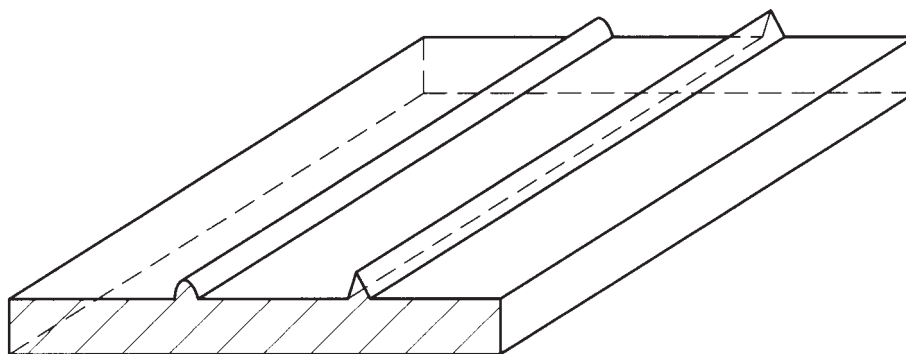


FIG. 21 RIDGES OR RIBS

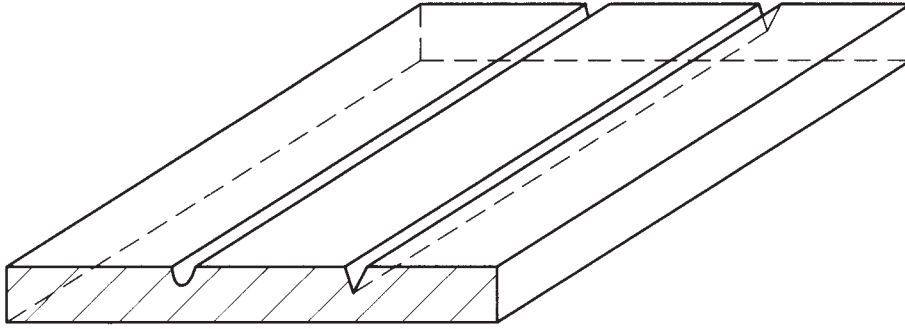


FIG. 22 GROOVES

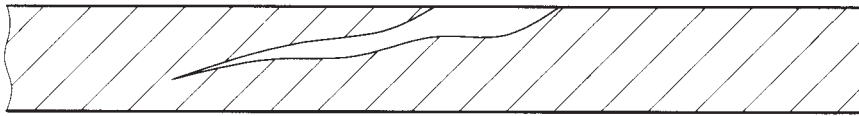
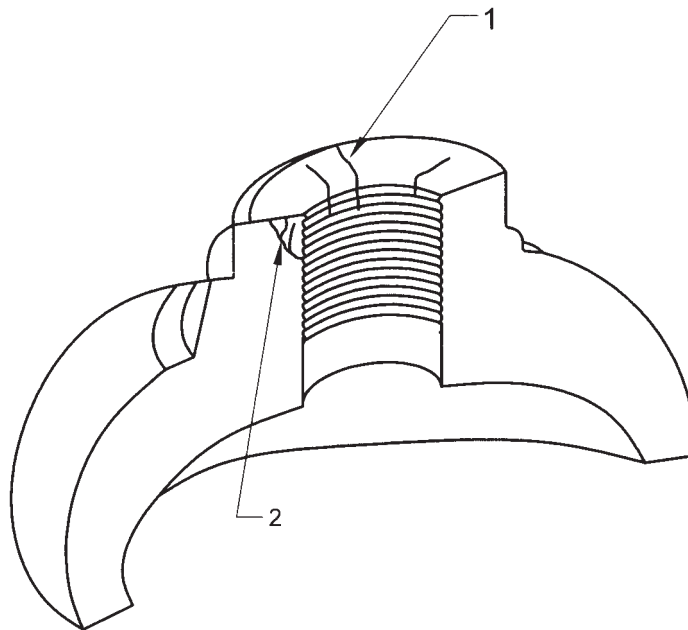


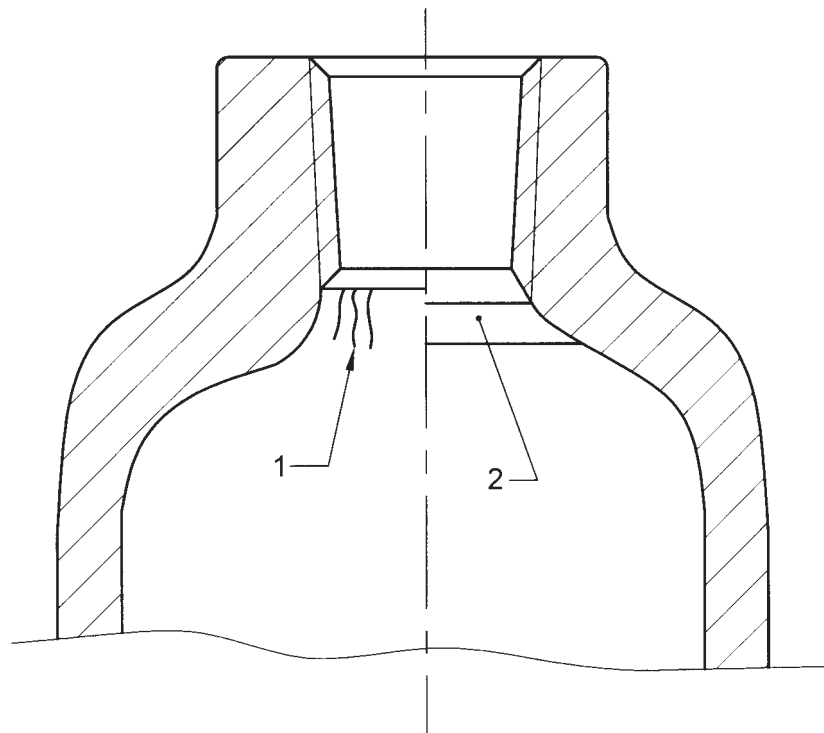
FIG. 23 LAMINATION



Key

- 1 — Neck cracks
- 2 — Propagated crack in the neck

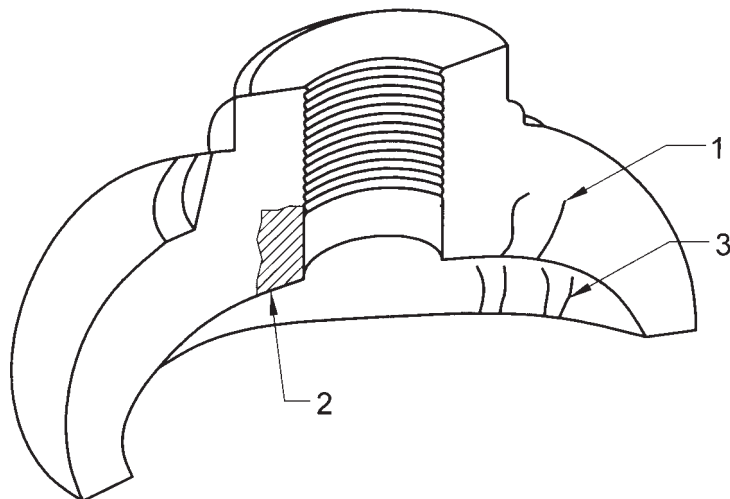
FIG. 24 NECK CRACKS



Key

- 1 — Folds or cracks
- 2 — After machining

FIG. 25 SHOULDER FOLDS AND CRACK



Key

- 1 — Shoulder cracks
- 2 — Propagated crack in the shoulder
- 3 — Folds

FIG. 26 SHOULDER CRACKS

ANNEX G
(Clauses 11 and 15)
PRODUCTION TEST CERTIFICATE

G-1 Application body.....
 Inspection body.....
 Date.....
 Type approval No.....
 Description of cylinder.....
 Production testing No.....
 Manufacturing batch No.....to.....
 Manufacturer.....(Name and address).....
Customer
(name and address).....

Table 5 Production Test — Measurements of Sample Cylinders

Sl No.	Test No.	Batch consisting of No..... to No.....	Water Capacity Litre	Mass Empty kg	Minimum Measured Thickness	
					Of the Wall mm	Of the Base mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)

Table 6 Production Tests — Mechanical Tests Carried Out on Sample Cylinders

Sl No.	Test/ Batch	Cast No.	Heat Treatment	Tensile Test Test-pieces in Accordance with IS 1608 Yield Stress R_{eH} MPa Tensile Strength R_m MPa Elongation, A percent	Bend Test 180° without Cracking	Hydraulic Burst Test Pressure	Description of the Fracture
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Minimum Values Specified							

I, the undersigned hereby declare that I have checked the requirement of the prototype testing of IS 15660 have been carried out satisfactorily.

Special remarks

General remarks

Certified on (date) Place.....

..... Signature of the Inspector.....

On behalf of (Inspection body).....

ANNEX H*(Foreword)***COMMITTEE COMPOSITION**

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This Indian Standard has been developed from Doc No.: MED 16 (1372).

Amendments Issued Since Publication

Amendment No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002

Telephones: 2323 0131, 2323 3375, 2323 9402

Website: www.bis.gov.in

Regional Offices:

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Published by BIS, New Delhi